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X-ray monitoring of optical novae in M 31 from July 2004 to February 2005⋆,⋆⋆,⋆⋆⋆

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ABSTRACT

Context. Optical novae have recently been identified as the major class of supersoft X-ray sources in M 31 based on ROSAT and early XMM-Newton and *Chandra* observations.
Aims. This paper reports on a search for X-ray counterparts of optical novae in M 31 based on archival *Chandra* HRC-I and ACIS-I as well as XMM-Newton observations of the galaxy center region obtained from July 2004 to February 2005.
Methods. We systematically determine X-ray brightness or upper limit for counterparts of all known optical novae with outbursts between November 2003 to the end of the X-ray coverage. In addition, we determine the X-ray brightnesses for counterparts of four novae with earlier outbursts.
Results. For comparison with the X-ray data we created a catalogue of optical novae in M 31 based on our own nova search programs and on all novae reported in the literature. We collected all known properties and named the novae consistently following the CBAT scheme. We detect eleven out of 34 novae within a year after the optical outburst in X-rays. While for eleven novae we detect the end of the supersoft source phase, seven novae are still bright more than 1200, 1600, 1950, 2650, 3100, 3370 and 3380 d after outburst. One nova is detected to turn on 50 d, another 200 d after outburst. Three novae unexpectedly showed short X-ray outbursts starting within 50 d after the optical outburst and lasting only two to three months. The X-ray emission of several of the novae can be characterized as supersoft from hardness ratios and/or X-ray spectra or by comparing HRC-I count rates with ACIS-I count rates or upper limits.
Conclusions. The number of detected optical novae at supersoft X-rays is much higher than previously estimated (>30%). We use the X-ray light curves to estimate the burned masses of the White Dwarf and of the ejecta.

Key words. galaxies: individual: M 31 – novae, cataclysmic variables – X-rays: galaxies – X-rays: binaries – catalogs

1. Introduction

The outbursts of classical novae (CNe) are caused by the explosive hydrogen burning on the white dwarf (WD) surface of a cataclysmic variable (CV), a close binary system with transfer of matter from a main sequence star to the WD. After 10^{-5}–10^{-4} $M_\odot$ of H-rich material are transfered to the WD, ignition in degenerate conditions takes place in the accreted envelope and a thermonuclear runaway is initiated (José & Hernanz 1998; Starrfield et al. 1998; Prialnik & Kovetz 1995). As a consequence, the envelope expands and causes the brightness of the star to increase to maximum luminosities up to $\sim 10^5$ $L_\odot$. A fraction of the envelope is ejected, while a part of it remains in steady nuclear burning on the WD surface. This powers a supersoft X-ray source (SSS) which can be observed as soon as the expanding ejected envelope becomes optically thin to soft X-rays, with the spectrum of a hot ($T_{\rm eff}$: 10^5–10^6 K) WD atmosphere (MacDonald & Vennes 1991). The duration of the SSS phase is inversely related to the WD mass while the turn-on of the SSS is determined by the mass ejected in the outburst. Models of the post-outburst WD envelope show that steady H-burning can only occur for masses smaller than $\sim 10^{-5}$ $M_\odot$ (Sala & Hernanz 2005b; Tuchman & Truran 1998), and the observed evolution of the SSS in V1974 Cyg has been successfully modeled by an envelope of $\sim 2 \times 10^{-6}$ $M_\odot$ (Sala & Hernanz 2005a). WD envelope models also show that the duration of the SSS state depends on the metalicity of the envelope, so the monitoring of the SSS states of CNe provides constraints also on the chemical composition of the post-outburst envelope. Hachisu & Kato (2006a) have developed envelope and optically thick wind models that simulate the optical, UV and X-ray light curves for several WD masses and chemical compositions, and have used them to successfully simulate the observed light curves of several novae (Hachisu & Kato 2005; Kato & Hachisu 2005, 2006).

Accreting WDs in recurrent novae (RNe) are good candidates for type Ia supernovae (SNe) as RNe are believed to contain massive WDs. However, one of the main drawbacks to make RNe believable progenitors of SNe-Ia was their low fraction in optical surveys (Della Valle & Livio 1994). In the case of CNe the ejection of material in the outburst makes it difficult to follow

⋆ Partly based on observations obtained with the Wendelstein Observatory of the Universitätssternwarte München.
⋆⋆ Appendices are only available in electronic form at
http://www.aanda.org
⋆⋆⋆ Tables A.1, A.2 and B.2 are only available in electronic form at the CDS via anonymous ftp to
cdsarc.u-strasbg.fr (130.79.128.5) or via
http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/465/375

the long-term evolution of the WD mass. For some CNe there is a disagreement between theory and observations regarding the ejected masses, with observational determinations of the mass in the ejected shell larger than predicted by models. The duration of the SSS state provides the only direct indicator of the post-outburst envelope mass in RNe and CNe. In the case of CNe with massive WDs, the SSS state is very short (<100 d) and could have been easily missed in previous surveys. CNe with short SSS state are additional good candidates for SNe-Ia progenitors which makes determining their frequency very important.

Nevertheless, the number of SSS states observed in novae is small. In a total of 39 CNe observed less than ten years after the outburst by ROSAT, SSS states were found only in three novae (Orio et al. 2001), with SSS phases lasting between 400 days and 9 years: GQ Mus (Ögelman et al. 1993), V1974 Cyg (Krautter et al. 1996), and Nova LMC 1995 (Orio & Greiner 1999; Orio et al. 2003). The *Chandra* and XMM-Newton observatories have detected SSS emission for three more novae: V382 Vel (Orio et al. 2002; Burwitz et al. 2002), V1494 Aql (Drake et al. 2003), and V4743 Sgr (Ness et al. 2003; Orio & Tepedelenlioglu 2004). But for most Galactic and LMC novae, only a limited number of observations have been performed for each source, providing little constraints on the duration of the SSS state. A recent exception is the monitoring of the recurrent nova RS Oph in spring 2006 with the Swift satellite which clearly determined the end of the SSS state after less than 100 days after outburst (see e.g. Osborne et al. 2006) which suggests a WD mass of 1.35 $M_\odot$ (Hachisu et al. 2006).

Although only X-ray observations can provide direct insight into the hot post-outburst WD, ultraviolet emission lines arising from the ionization of the ejecta by the central X-ray source reflect the presence of on-going hydrogen burning on the WD surface. Several works have used this indirect indicator to determine the turn-off of classical novae from IUE observations (Shore et al. 1996; Gonzalez-Riestra et al. 1998; Vanlandingham et al. 2001), showing in all cases turn-off times shorter than expected.

The small number of novae found to exhibit a SSS state, and the diversity of the duration of this state (from 10 years down to few weeks) are one of the big mysteries in the study of hydrogen burning objects over the last years. Despite an extensive ToO program with *Chandra* and XMM-Newton (of order 3 dozen observations during the last 6 years), little progress has been made in constraining the duration of the SSS states, or to even putting constraints on the long term evolution of accreting WDs in binary systems.

In contrast to the Galaxy, X-ray observations of the central area of the big nearby spiral galaxy M 31 (distance 780 kpc, Holland 1998; Stanek & Garnavich 1998), with its moderate Galactic foreground absorption ($N_{\rm H} = 6.66 \times 10^{20}$ cm^{-2}, Stark et al. 1992), offer the unique chance to learn more about the duration of the SSS phase in novae with minimal effort: M 31 is the only nearby galaxy with many (more than 100 nova explosions are known from the center area over the last 5 years!) reported optical novae within the field of view (FOV) of one XMM-Newton EPIC or *Chandra* HRC-I or ACIS observation. All novae are at the same, known distance, thus allowing easy comparison of light curves and maximum brightness/luminosity in optical and X-rays.

Recently, Pietsch et al. (2006, 2005a, hereafter PFF2005) combined an optical nova catalogue from the WeCAPP survey with optical novae reported in the literature and correlated them with the most recent X-ray catalogues from ROSAT, XMM-Newton and *Chandra*, and – in addition – searched for nova correlations in archival data. They reported 21 X-ray counterparts for novae in M 31 – mostly identified as supersoft sources (SSS) by their hardness ratios – and two in M 33. Their sample more than triples the number of known optical novae with supersoft X-ray phase. For most of the counterparts, X-ray light curves could be determined. From the well determined start times of the SSS state in two novae, the hydrogen mass ejected in the outburst could be determined to $\sim 10^{-5}$ $M_\odot$ and $\sim 10^{-6}$ $M_\odot$, respectively. The supersoft X-ray phase of at least 15% of the novae started within a year. At least one of the novae showed a SSS state lasting 6.1 years after the optical outburst. Six of the SSSs turned on between 3 and 9 years after the optical discovery of the outburst and may be interpreted as recurrent novae. If confirmed, the detection of a delayed SSS phase turn-on may be used as a new method to classify novae as recurrent. The new method yielded a ratio of recurrent novae to classical novae of 0.3 which is in agreement (within the errors) with previous works.

For one of these six cases (source 191 from the XMM-Newton catalogue of M 31 X-ray sources Pietsch et al. 2005b, hereafter PFH2005), Smirnova & Alksnis (2006) showed that the SSS was correlated with a nova which was detected on optical images 84 days before the X-ray detection (M31N 2001-10f). The position of this nova differs from that of the nova close-by proposed as identification by PFF2005. Therefore the explanation as recurrent nova is no longer necessary for this system.

Recently, Smirnova et al. (2006) reported the identification of another transient SSS in the M 31 northern disk, [PFH2005] 543 = XMMU J004414.0+412204 = n1-86 (Trudolyubov et al. 2002; Garcia et al. 2002; Trudolyubov et al. 2005; Williams et al. 2006), with an optical nova (M31N 2001-11a, see Table A.1). The nova outburst in November 2001 happened 53 days before the detection as SSS. After the first SSS in M 31 identified with a nova, M31N 1990-09a (Nedialkov et al. 2002) and M31N 2001-10f, M31N 2001-11a is already the third optical nova in M 31 for which the optical outburst was detected when searching for optical counterparts of supersoft X-ray sources.

Here we report on a follow-up of the PFF2005 work based on archival *Chandra* HRC-I and ACIS-I as well as XMM-Newton observations of the M 31 center area collected from July 2004 to February 2005. The optical nova catalog used for the correlation contains many novae detected by Kamil Hornoch (Appendix B) and the WeCAPP project and additional novae from the literature (see Sect. 2 and Appendix A). During this work we created an M 31 optical nova catalog from the literature that contains ~700 optical nova candidates with references for parameters (like positions, date of outburst, brightness and filter, optical spectra, X-ray detection). We homogeneously name the M 31 novae following the CBAT naming scheme (see Appendix B) that we want to update regularly in an internet version. In Sect. 3, we discuss the X-ray observations and methods used. In Sect. 4 we give light curves and upper limits, and X-ray spectral information for counterparts of M 31 novae. Based on these results we argue that X-ray SSS states are significantly more common in optical novae than reported before. We discuss ejected masses and WD masses derived from the X-ray light curves. We also discuss the special case of nova M31N 2004-11f, the first nova in M 31 detected in Hubble Space Telescope (HST) images and probably a recurrent nova, which is one of the two novae in M 31 detected in X-rays within 35 days after the optical outburst (Sect. 5).

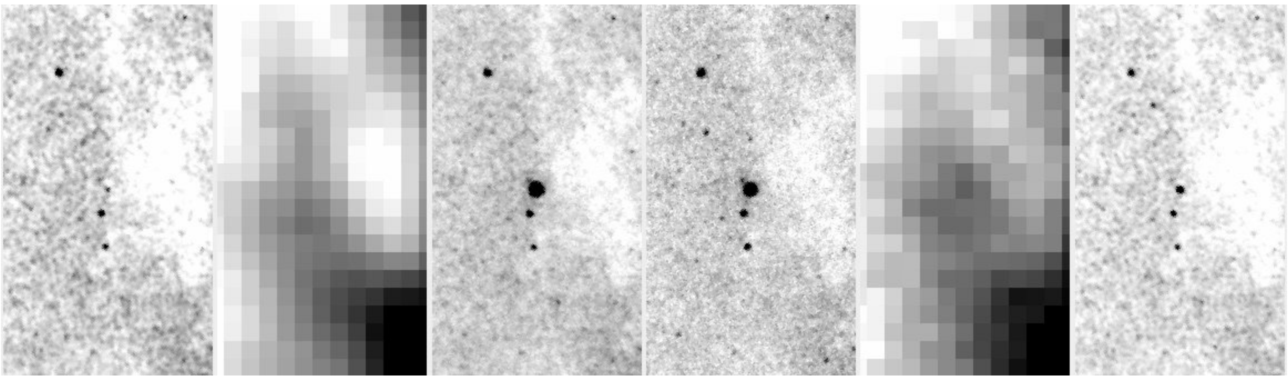

Fig. 1. Images of M31N 2004-11f: *from the left to the right* HST-ACS (*F435W*) 2004-01-23, Wendelstein (R) 04-10-25, HST-ACS (FR423N) 2004-11-02, HST-ACS (FR388N) 2004-11-08, Wendelstein (R) 04-11-09, HST-ACS (*F435W*) 2004-11-22. The different bands are given in brackets. The angular scale of each image is 6″ × 10.5″. Note that already in the first image the pre-nova is clearly identified. Due to the lower resolution the faint source is not visible in the second image taken on Wendelstein previous to the nova outburst. After the outburst the nova is also visible in the fifth image from Wendelstein.

2. M 31 optical nova catalogue

The optical novae used for cross-correlation with the X-ray data result in part from 8 years of observations (September 1997 to February 2005) of the central part of M 31 by the continuing Wendelstein Calar Alto Pixellensing Project (WeCAPP, Riffeser et al. 2001). WeCAPP monitors a 17.2′ × 17.2′ field centered on the nucleus with the 0.8 m telescope at Wendelstein Observatory (Germany) continuously since 1997. The observations are carried out in *R* and *I* filters close to the Kron-Cousins system. Data were reduced using the WeCAPP reduction pipeline mupipe, which implements an image subtraction technique (Alard & Lupton 1998) to overcome the crowding effects and allow proper photometry of variable sources in the central bulge of M 31 (Riffeser et al. 2003).

In the full WeCAPP data set, 23 781 variable sources were detected, most of them being Long Period Variables (Fliri et al. 2006). The 1σ error radius of the astrometric solution is 0.″16.

A catalogue of more than 75 novae brighter than 20.0 mag detected in the survey is in preparation (Fliri et al. 2007, hereafter FBR2007). The outburst of six of the novae in 2005 occurred after the X-ray observations. An example for an optical light curve of a nova which correlates with a time variable SSS detected by XMM-Newton and *Chandra*, was shown in Fig. 1 of PFF2005 (nova M31N 2000-07a = WeCAPP-N2000-03).

We combined the WeCAPP nova list with novae from other surveys of M 31. Many of them are listed in the nova pages “M 31 (Apparent) Novae Page” provided by the International Astronomical Union, Central Bureau for Astronomical Telegrams CBAT and the finding charts and information, collected by David Bishop (see Appendix A). Of specific interest for the X-ray correlations were the many novae detected by Kamil Hornoch and collaborators in 2003 to 2005 for which we give position and light curve information in Appendix B. Throughout the paper, we use the CBAT nova nomenclature (see Appendix A). We also adopted this naming scheme for novae that were not registered by CBAT. For the WeCAPP and Hornoch novae we estimated the time interval between maximum brightness and two magnitudes below. We derived these t_2 timescales with a very simple algorithm. First we evaluated the observed maximum brightness and its Julian date. Starting from this point we searched for later points, where the interpolated (decreasing) line between two data points is crossing a brightness 2 mag fainter than the maximum. The difference between this time and the maximum time gives a good guess for the t_2 timescale.

For the detailed search for X-ray emission, we use all optical novae in the FOV of the *Chandra* HRC-I with outbursts from 13 months before to the time of the deep X-ray observations (i.e. five in November/December 2003, 29 in 2004 and two in January/February 2005).

There are three optical novae in 2004 that need a special discussion:

M31N 2004-07a was detected by Fiaschi et al. (2004, see `http://cfa-www.harvard.edu/iau/CBAT_M31.html`) on Hα filter images on July 30, 2004. In the WeCAPP catalogue there is a nova within 4″ of the position (WeCAPP N2004-06) which was detected on *R* band images on November 5, 2004 when that field was covered for the first time after a gap of nearly half a year. A search on Ondřejov observatory *R* filter and La Palma observatory Hα filter images (see Nova No. 41 in Appendix B) revealed that both detections are from the same nova outburst, that the position of the nova is close to that given by WeCAPP, and that it was a slow nova with an outburst well before the first Hα filter detection.

Nova M31N 2004-11g was detected in the WeCAPP survey (WeCAPP N2004-10) on November 10, 2004 after a gap in the observations of 15 days. A search on Lelekovice and Ondřejov *R* filter images (see Nova No. 40 in Appendix B) revealed that the nova outburst occurred at least 4 days earlier.

Nova M31N 2004-11f was detected in the WeCAPP survey (WeCAPP N2004-11) on November 10, 2004 in the same field. Its position close to the M 31 center prevented the detection in Lelekovice and Ondřejov images. However, a search in archival HST ACS images showed the nova in outburst on three images on 2004 November 2, 8, and 22 (8 and 2 days before and 12 days after the WeCAPP detection), while it is also detected in the pre-nova stage on 2004 January 23. For the ACS data we carried out an absolute photometric calibration in the *F435W* band for the date JD = 2 453 331 using a zero point in the *B* band of 25.779 mag. This is consistent with the zero point given in De Marchi et al. (2004). The absolute calibration was checked using the globular cluster [BHB2000] 124-NB10 yielding 15.94 mag in *B* consistent with the published (Barmby et al. 2000) value of 15.87 mag. We thus estimate an accuracy for the *F435W*-band measurements of roughly 0.1 mag. All HST/ACS data points were obtained by differential photometry in respect to four different stars in each ACS image. The scatter

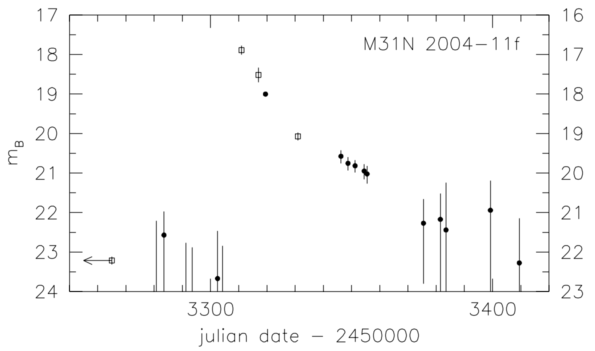

Fig. 2. In this figure we present the first nova in M 31 detected in ground and space data (HST). The Nova M31N 2004-11f light curve consists of four data points obtained with HST/ACS in the blue band using the *F435W* (JD = 2 453 027 and JD = 2 453 331), FR423N (JD = 2 453 311) and *FR388N* (JD = 2 453 317) filters, respectively and plotted as open squares. The first HST *F435W* image provides a good estimate for the brightness about 9 months before the eruption (the arrow-marked data point), which translates in a minimum outburst amplitude of 5.3 mag in the *B* band and a maximum (observed) brightness of B = 17.9 mag (see scale at left y-axis). Additionally 16 WeCAPP data points were obtained in the R-band (scale at right y-axis) with the 0.8 m Wendelstein telescope which are shown as filled circles with their 3σ error bars.

of the magnitudes derived from these stars give a rough estimate for the errors (see Figs. 1 and 2). Already in the HST image taken about 9 months before the eruption the pre-nova is clearly identified. Its estimated brightness in outburst of $B = 17.9$ mag and the minimal outburst amplitude of 5.3 mag in the B band are well consistent with M31N 2004-11f being a recurrent nova in a symbiotic system like e.g. RS Oph (see also Hachisu 2003). Already three nova outbursts have been reported from within 2 arcsec of the position of M31N 2004-11f (see Table 1). A detailed astrometry of the three WeCAPP detections shows that the positions of the corresponding novae are not the same. However, M31N 2004-11f may still be a recurrence of nova M31N 1984-07a. From the WeCAPP data we estimated the decay time from maximum brightness to a brightness two magnitudes below ($t_{2\mathrm{R}}$) to 28.4 d.

3. X-ray observations and methods used for the M 31 nova search

The search for X-ray counterparts of optical novae in M 31 reported in PFF2005 used XMM-Newton and *Chandra* observations collected till June 2002. After that there were mainly three groups of X-ray observations pointing to the M 31 center area which we extracted from the archive and analyzed for X-ray counterparts of optical novae.

- Four 50 ks *Chandra* HRC-I observations to monitor M 31* (the nuclear source in M 31 corresponding to Cen A* in the Galaxy) with about one month spacing which are partly split in two ObsIDs on the same day (PI Garcia).
- Several short (≤5 ks) *Chandra* ACIS-I observations of the M 31 bulge area to detect and monitor black hole X-ray transients separated by about a month (PIs Garcia, Murray).
- Four 20 ks XMM-Newton observations within four days to monitor the low mass X-ray binary RX J0042.6+4115 (PI Barnard) located 1.1′ to the west of the M 31 nucleus position.

We give an observation log of the *Chandra* and XMM-Newton observations newly analyzed in Tables 2 and 3. There are several

Table 1. Detection of novae within 2″ of M31N 2004-11f.

Name[a] M31N	RA (h:m:s) Dec (d:m:s) J2000	Δ_{RA} Δ_{Dec} (″)	JD[b] T (a)[d]	Brightness (mag) band	Ref.[c]
1984-07a	00:42:47.2	0.6	5909.5	17.6:	(1)
	+41:16:20	0.2	0.0	B	
2001-10c	00:42:47.21	0.7	12193.5	17.4	(2)
	+41:16:18.7	1.1	17.2	R	
2004-02a	00:42:47.27	1.4	13039.3	16.6	(3)
	+41:16:21.4	1.6	19.5	R	
2004-11f	00:42:47.15	0.0	13311.8	17.9	(4)
	+41:16:19.8	0.0	20.3	R	

Notes: [a] following CBAT nomenclature (see text); [b] Julian Date - 2 440 000; [c] Detection reference: (1) R137, Rosino et al. (1989); (2) WeCAPP N2001-14, FBR2007; (3) WeCAPP N2004-03, FBR2007; (4) WeCAPP N2004-11, FBR2007, this work; [d] time from first reported outburst in the field in years.

earlier *Chandra* ACIS-I observations to the center of M 31 from August 2002 to May 2004 (ObsID 4360, 4678 – 4682, 4691). However, no novae were detected and we therefore do not show them in Table 2. We checked for offsets of the *Chandra* position solution from the nominal aspect solution using the point source catalogues of Kong et al. (2002, hereafter KGP2002) and Kaaret (2002, hereafter K2002). No significant offsets were found (≤0.2″). For the analysis we merged ObsIDs 6177 and 5926 as well as 6202 and 5927 as they were performed within a day. To be more sensitive for nova M31N 1995-09b we determined the flux combining all HRC observations of Table 2. Count rates and 3σ upper limits have been corrected for reduced off-axis effective area, assuming a soft spectrum. At 10′ off-axis for the *Chandra* high resolution mirror assembly HRMA the area is reduced to about 85% as given in the *Chandra* calibration database v.3.2.1.

For the XMM-Newton source detection, we rejected times with high background (ObsID 0202230301 is totally rejected as it shows high background throughout the observation). To increase the detection sensitivity we merged the data of ObsIDs 0202230201, 0202230401 and 0202230501 after correction of the position offset. Within the three day time-span of the observations one would not expect strong brightness changes of a nova. For the spectral analysis of nova M31N 1999-10a we used a less stringent background screening as we were only interested in energies below 1 keV and even could use part of ObsID 0202230301. Parameters of individual observations are summarized in Table 3. In Tables 6 and 7 we assume an average JD for these observations of 2 453 205.5.

We calculated intrinsic luminosities or 3σ upper limits in the 0.2–1.0 keV band starting from the 0.2−1 keV count rates or upper limits in EPIC and ACIS I and the full count rates or upper limits in the *Chandra* HRC and assuming a black body spectrum and Galactic foreground absorption. Table 4 gives energy conversion factors for the different instruments for 40 eV and 50 eV black body temperatures. As one can see the ECFs strongly change with the softness of the spectrum. Additional absorption within M 31 would heavily change the observed count rate. An extrapolation to the bolometric luminosity of a nova at a time is very uncertain and this is even more so as the temperatures of novae may vary with time after outburst and from nova to nova and may well correspond to a spectrum even softer than 30 eV.

To classify X-ray sources as SSS, we here use XMM-Newton EPIC and *Chandra* ASIS-I spectra. Unfortunately, many of the

Table 2. Log of archival *Chandra* observation to the M 31 center from July 2004 to February 2005.

Instr.	ObsID	Obs. dates	JD $^+$ (2 450 000+)	Pointing direction RA/Dec (J2000)		t_{exp} (ks)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
ACIS-I	4719	2004-07-17	3204.48	0:42:42.98	41:16:51.8	4.12
ACIS-I	4720	2004-09-02	3251.13	0:42:43.53	41:16:22.6	4.11
ACIS-I	4721	2004-10-04	3283.40	0:42:40.24	41:16:14.2	4.13
ACIS-I	4722	2004-10-31	3309.61	0:42:41.10	41:15:40.7	3.90
ACIS-I	4723	2004-12-05	3344.91	0:42:49.42	41:16:29.6	4.04
HRC-I	5925	2004-12-06	3346.6	0:42:43.91	41:15:54.4	46.3
HRC-I	6177	2004-12-27	3366.9	0:42:44.22	41:15:53.8	20.0
HRC-I	5926	2004-12-27	3367.5	0:42:44.24	41:15:53.3	28.3
HRC-I	6202	2005-01-28	3398.7	0:42:44.64	41:15:53.9	18.0
HRC-I	5927	2005-01-28	3399.5	0:42:44.65	41:15:53.7	27.0
HRC-I	5928	2005-02-21	3423.5	0:42:44.98	41:15:55.0	44.9

Notes: $^+$ Julian Date at mid of observation.

Table 3. Log of archival XMM-Newton observation to the M 31 center in July 2004.

ObsID	Obs. dates	JD $^+$ (2 450 000+)	Pointing direction RA/Dec (J2000)		Offset *	EPIC $t^{\dagger}_{exp}$ (ks) PN	MOS1	MOS2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0202230201	2004-07-16	3203.30	0:42:38.58	41:16:03.8	−1.3, −1.2	16.4 (16.4)	19.4	19.4
0202230301	2004-07-17	3204.15	0:42:38.58	41:16:03.8	−1.0, −0.9	0.0 (18.6)	0.0	0.0
0202230401	2004-07-18	3205.62	0:42:38.58	41:16:03.8	−1.7, −1.5	12.4 (12.8)	17.9	17.9
0202230501	2004-07-19	3206.19	0:42:38.58	41:16:03.8	−1.4, −1.8	8.0 (19.4)	10.2	10.2

Notes: $^+$ Julian Date at mid of observation; * systematic offset in RA and Dec in arcsec determined from correlations with 2MASS, USNO-B1 and *Chandra* catalogues; † dead time corrected exposure time in units of ks after screening for high background. In brackets we give the PN exposure time used for the spectral analysis of nova M31N 1999-10a. All observations in full frame imaging mode with medium filter.

novae in 2004 are only detected with the *Chandra* HRC-I and can not be classified by this instrument. Nevertheless, several of these novae can indirectly be classified as SSS if they are detected in the *Chandra* HRC-I observation 5925. We then can make use of the *Chandra* ACIS-I observation 4723 performed 1.7 days earlier. Under the assumption that the novae did not change X-ray brightness and spectrum between these observations, we can check if the corresponding X-ray source had a soft spectrum by comparing ACIS-I count rates or upper limits with HRC-I count rates. Table 5 gives count rate conversion factors from HRC-I to ACIS-I for different spectral models assuming Galactic foreground absorption. While hard or moderately hard spectra lead to conversion factors above one, typical supersoft spectra as found in novae show conversion factors below 0.5. Classification of spectra via this method are indicated in Tables 6 and 7 with "(ACIS-I)" under comments.

4. M 31 optical nova detected with Chandra and/or XMM-Newton

We searched for X-ray emission from nova counterparts using two methods with results presented in Tables 6 and 7, respectively. The novae in the tables are sorted with ascending time of outburst.

First, we searched for X-ray flux or upper limits for optical nova counterparts that had been detected in X-rays by PFF2005 and were still X-ray active at the last observations analyzed by PFF2005 (beginning of 2002). We added optical nova counterparts that were newly detected in the 2004/5 X-ray observations if the optical outburst of the nova was before November 2003 (see Table 6). In the covered field, the density of novae is rather high and the positions of novae with outbursts before 1995 are often not as well determined (see Table A.1). In addition, one would only expect the start of the SSS state later than 10 years after outburst for novae under extreme conditions (low WD mass and core material with close to solar abundance, see Hachisu & Kato 2006a). We therefore constrained the search for new X-ray

Table 4. Count rate conversion factors to un-absorbed fluxes (ECF) into the 0.2−1 keV band for black body models with temperatures of 40 eV and 50 eV for different instruments and filters, including a Galactic foreground absorption of 6.66×10^{20} cm^{-2}.

Detector	Filter	40 eV	50 eV
		(10^{-11} erg cm^{-2} ct^{-1})	
EPIC PN	medium	2.15	1.22
EPIC MOS1	medium	11.4	5.94
EPIC MOS2	medium	11.1	5.78
Chandra HRC-I		9.17	6.76
Chandra ACIS-I		152.	55.6

Table 5. Count rate conversion factors from *Chandra* HRC-I to the full energy band of *Chandra* ACIS-I for different spectra derived for *Chandra* Cycle 6 using PIMMS v3.7. For all spectra we assume a Galactic foreground absorption of 6.66×10^{20} cm^{-2}. Model spectra include: power law with photon index of 1.7 (PL), thermal bremsstrahlung with a temperature of 1 keV (BR) and three black body spectra (BB) of different temperature.

Spectrum	PL (α) 1.7	BR (kT) 1.0 keV	BB (kT) 70 eV	50 eV	30 eV
ACIS-I/HRC-I	1.81	1.33	0.28	0.133	0.023

Table 6. XMM-Newton, *Chandra* and ROSAT measurements of M 31 optical nova candidates.

Optical nova candidate				X-ray measurements					
Name M31N	RA (h:m:s)[a] Dec (d:m:s)[a]	Offset[b] (′)	JD[c] 2 440 000+	Source name[d]	D (″)	Observation[e] ID	ΔT^{f} (d)	$L_{\rm X}^{g}$ (10^{36} erg s^{-1})	Comment
1994-09a	0:42:42.08	3.87	9622.5			c3 (EPIC)	2467	<0.6	
=	41:12:18.0			J004242.1+411218	0.7	1912 (HRC-I)	2591	1.2 ± 0.4	K2002
AGPV 1576				[PFH2005] 313	3.1	c4 (EPIC)	2658	1.6 ± 0.2	SSS
						mrg (EPIC)	3583	<0.4	
1995-09b	0:42:43.10	0.24	9963.5			268 (HRC-I)	1572	<7.0	
=	41:16:04.1					309 (ACIS S)	1734	10.2 ± 2.7	
RJC99						310 (ACIS S)	1765	16.1 ± 3.6	
Sep-95						1854 (ACIS S)	1960	11.5 ± 3.1	
				r1-35	1.1	1575 (ACIS S)	2224	13.4 ± 1.2	SSS-HR, DKG2004
				J004243.1+411604	0.2	1912 (HRC-I)	2250	8.8 ± 0.8	K2002
						2905 (HRC-I)	2327	$22.5^{+12.0}_{-8.5}$	
						mrg (HRC-I)	3383	0.6 ± 0.2	
1995-11c	0:42:59.3	2.87	10049.5			400780h (HRI)	37	<5.8	
=	41:16:42					268 (HRC-I)	1486	7.7 ± 2.9	
[SI2001]						309 (ACIS S)	1648	8.9 ± 2.6	
1995-05				[PFH2005] 369	2.1	c1 (EPIC)	1671	2.3 ± 0.5	SSS
						310 (ACIS S)	1679	13.8 ± 3.3	
				[PFH2005] 369	2.1	c2 (EPIC)	1857	3.0 ± 0.8	SSS
						1854 (ACIS S)	1874	7.1 ± 2.4	
				[PFH2005] 369	2.1	c3 (EPIC)	2040	4.7 ± 0.5	SSS
				r2-63	0.8	1575 (ACIS S)	2138	11.4 ± 1.0	SSS-HR, DKG2004
				J004259.3+411643	1.3	1912 (HRC-I)	2164	10.5 ± 0.9	K2002
				[PFH2005] 369	2.1	c4 (EPIC)	2231	7.6 ± 0.4	SSS
						2906 (HRC-I)	2378	$16.8^{+9.7}_{-7.1}$	
						mrg (EPIC)	3156	3.0 ± 0.4	SSS
						5925 (HRC-I)	3296	4.6 ± 0.9	
						5926m (HRC-I)	3317	4.1 ± 0.9	
						5927m (HRC-I)	3349	3.9 ± 0.9	
						5928 (HRC-I)	3373	2.6 ± 0.8	
1996-08b	0:42:55.2	5.06	10307.5			c3 (EPIC)	1782	<1.0	recurrent nova
=	41:20:46					1575 (ACIS S)	1880	2.2 ± 0.8	
GCVS-M31-				J004255.3+412045	1.2	1912 (HRC-I)	1906	2.9 ± 0.8	K2002
V0962				[PFH2005] 359	1.1	c4 (EPIC)	1973	3.4 ± 0.2	SSS
						mrg (EPIC)	2898	2.0 ± 0.3	SSS
						5925 (HRC-I)	3038	2.8 ± 0.9	
						5926m (HRC-I)	3059	4.0 ± 0.9	
						5927m (HRC-I)	3091	5.6 ± 1.0	
						5928 (HRC-I)	3115	3.4 ± 0.9	
1997-08b	0:42:50.5	8.42	10691.5			c3 (EPIC)	1398	<1.2	
=	41:07:48					1912 (HRC-I)	1522	<3.7	
[SI2001]				[PFH2005] 347	2.3	c4 (EPIC)	1589	0.7 ± 0.2	SSS
1997-09						mrg (EPIC)	2514	<0.3	
1997-11a	0:42:42.13	1.05	10753.6			1575 (ACIS S)	1434	<0.7	recurrent nova
	41:15:10.5					1912 (HRC-I)	1461	<0.7	
				J004242.1+411511	0.5	5925 (HRC-I)	2593	3.4 ± 0.7	
						5926m (HRC-I)	2614	4.4 ± 0.7	
						5927m (HRC-I)	2646	4.2 ± 0.7	
						5928 (HRC-I)	2670	4.1 ± 0.7	
1998-06a	0:43:28.76	10.04	10970.5			c1 (EPIC)	750	<1.0	recurrent nova
=	41:21:42.6					c2 (EPIC)	936	<1.7	
GCVS-M31-				[PFH2005] 456	1.1	c3 (EPIC)	1119	1.3 ± 0.4	SSS
V1067						1912 (HRC-I)	1243	<5.0	
				[PFH2005] 456	1.1	c4 (EPIC)	1310	1.7 ± 0.3	SSS
						mrg (EPIC)	2235	<0.4	

counterparts to novae with outburst after 1995 to suppress spurious detections.

Then we systematically searched for X-ray emission from all optical novae in the region covered by the FOV of the X-ray instruments with outburst times between November 2003 and the end of the X-ray coverage in February 2005, giving fluxes or upper limits for counterparts (see Table 7). To visualize the large number of novae in the central area of M 31 that were X-ray active during December 2004 to February 2005, we have marked them on a merged *Chandra* HRC-I image (Fig. 3).

Table 6. continued.

Optical nova candidate				X-ray measurements					
Name M31N	RA (h:m:s)[a] Dec (d:m:s)[a]	Offset[b] (′)	JD[c] 2 440 000+	Source name[d]	D (″)	Observation[e] ID	ΔT^{f} (d)	$L_{\rm X}^{g}$ (10^{36} erg s^{-1})	Comment
1999-10a	0:42:49.7	1.08	11454.7			1575 (ACIS S)	733	<0.7	
	41:16:32					1912 (HRC-I)	760	<0.8	
						mrg (EPIC)	1751	10.5 ± 0.9	SSS
				J004249.7+411633	1.6	5925 (HRC-I)	1892	21.2 ± 1.6	
						5926m (HRC-I)	1913	20.8 ± 1.5	
						5927m (HRC-I)	1944	19.2 ± 1.5	
						5928 (HRC-I)	1969	20.5 ± 1.5	
2000-08a	0:42:47.44	1.17	11719.6[<]			310 (ACIS S)	9	<2.2	
=	41:15:07.6					1854 (ACIS S)	203	<4.2	
WeCAPP-						1570 (HRC-I)	352	$16.8^{+9.7}_{-7.1}$	
N2000-05				r2-61	1.7	1575 (ACIS S)	468	9.6 ± 1.0	SSS-HR, DKG2004
				J004247.4+411507	0.2	1912 (HRC-I)	494	5.2 ± 0.6	K2002
						5925 (HRC-I)	1627	<1.3	
2000-07a	0:42:43.97	1.78	11753.0[*]			c1 (EPIC)	–32	<0.7	
=	41:17:55.5					c2 (EPIC)	154	<1.4	
WeCAPP-						1854 (ACIS S)	170	7.1 ± 2.4	
N2000-03				[PFH2005] 320	1.3	c3 (EPIC)	337	9.5 ± 0.7	SSS
				r2-60	0.8	1575 (ACIS S)	435	13.4 ± 1.2	SSS-HR, DKG2004
				J004243.9+411755	0.3	1912 (HRC-I)	461	8.4 ± 0.8	K2002
				[PFH2005] 320	1.3	c4 (EPIC)	528	5.5 ± 0.4	SSS
						mrg (EPIC)	1453	13.5 ± 0.7	SSS
						5925 (HRC-I)	1591	12.0 ± 1.2	
						5926m (HRC-I)	1612	12.3 ± 1.2	
						5927m (HRC-I)	1644	12.2 ± 1.2	
						5928 (HRC-I)	1668	9.6 ± 1.1	
2001-08d	0:42:34.61	2.76	12150.6[*]			c3 (EPIC)	–61	<0.5	close to
=	41:18:13.0					1575 (ACIS S)	37	<1.9	[PFH2005] 287
WeCAPP-					~1	1912 (HRC-I)	63	0.6 ± 0.3	
N2001-12					2.5	c4 (EPIC)	130	0.7 ± 0.1	SSS
						mrg (EPIC)	1055	<0.4	
2001-10a	0:43:03.31	5.32	12186.4[*]			mrg (EPIC)	1019	<1.5	
	41:12:11.5					5925 (HRC-I)	1158	3.4 ± 1.1	
						5926m (HRC-I)	1179	2.2 ± 0.9	
						5927m (HRC-I)	1211	5.2 ± 1.3	
				J004303.2+411211	0.9	5928 (HRC-I)	1235	3.7 ± 1.0	
2001-10f	0:41:54.26	12.86	12196.3			1912 (HRC-I)	17	<6.7	not [SI2001] 1992-01[*]
	41:07:23.9			[PFH2005] 191	0.9	c4 (EPIC)	84	37.0 ± 1.7	SSS
				[PFH2005] 191	0.9	s1 (EPIC)	90	13.1 ± 0.7	SSS
						mrg (EPIC)	1009	<0.8	
2002-01b	0:42:33.89	2.99	12282.3[<]			c4 (EPIC)	–2	<0.5	
=	41:18:23.9					2905 (HRC-I)	8	<9.1	
WeCAPP-					~0.2	2906 (HRC-I)	146	$27.5^{+12.0}_{-9.5}$	
N2002-01						mrg (EPIC)	925	<0.3	

Notes: [a] RA, Dec are given in J2000.0; [b] projected distance from M 31 nucleus position ($\mathrm{RA}_{\mathrm{J2000}} = 00^{\mathrm{h}}42^{\mathrm{m}}44\overset{\mathrm{s}}{.}324$, $\delta_{\mathrm{J2000}} = +41°16'08\overset{''}{.}53$; Crane et al. 1992); [c] * indicates well defined start date of optical outburst, < outburst start before, else badly defined (see text); [d] full source names from K2002 are CXOM31 Jhhmmss.s+ddmmss; [e] for XMM-Newton c1 corresponds to ObsID 0112570401, c2 to 0112570601, c3 to 0112570701, c4 to 0112570101 and s1 to 0112570201 (see PFF2005); "mrg (EPIC)" indicates the merged data of ObsID 0202230201, 0202230401, and 0202230501; for *Chandra* we give ObsID and camera used (see text). 5926m indicate the merged data of ObsIDs 6177 and 5926, 5927 m those of 6202 and 5927; "mrg (HRC-I)" indicates the merged data of ObsIDs 5925–5928, 6177 and 6202; [f] time after observed start of optical outburst; [g] un-absorbed luminosity in 0.2−1.0 keV band assuming a 50 eV black body spectrum with Galactic absorption, upper limits are 3σ; * wrong identification by PFF2005 (see Smirnova & Alksnis 2006).

4.1. *X-ray detections and upper limits for nova candidates more than a year after outburst*

In the 2004/2005 data, we searched for X-ray emission from the eleven M 31 optical novae that did not finish their SSS state before the last X-ray observations reported by PFF2005, i.e. by January 2002. In addition we detected three novae with optical outbursts from 1997 to 2001 that got X-ray active after January 2002. Results on these novae are summarized in Table 6. We give nova name (with reference to the name used by PFF2005) in Col. 1, optical position (J2000.0, Col. 2), distance from M 31 center (3), and Julian date JD of start of outburst (4). We indicate if the time of outburst is well defined (to better than 5 days), or if the outburst occurred most likely before the given epoch or is not well defined. As X-ray information we give the

Table 7. X-ray detections and upper limits of M 31 optical nova candidates within about a year after outburst using *Chandra* and XMM-Newton observations from July 2004 to February 2005.

Optical nova candidate				X-ray measurements					
Name M31N	RA (h:m:s)[a] Dec (d:m:s)[a]	Offset[b] (′)	JD[c] 2 450 000+	Source name[d]	D (″)	Observation[e] ID	ΔT[f] (d)	L_X[g] (10^{36} erg s^{-1})	Comment
2003-11a	0:42:53.78	3.17	2948.5[*]			mrg (EPIC)	257	<2.5	
	41:18:46.2			J004253.7+411846	0.2	5925 (HRC-I)	397	22.7 ± 1.7	SSS (ACIS-I)
						5926m (HRC-I)	418	27.6 ± 1.8	
						5927m (HRC-I)	450	21.2 ± 1.6	
						5928 (HRC-I)	474	21.1 ± 1.6	
2003-11b	0:43:00.76	5.62	2973.4[*]			mrg (EPIC)	232	<0.9	
	41:11:26.9			J004300.7+411126	0.5	5925 (HRC-I)	372	9.0 ± 1.3	soft (ACIS-I)
						5926m (HRC-I)	393	8.4 ± 1.2	
						5927m (HRC-I)	425	9.1 ± 1.3	
						5928 (HRC-I)	449	10.4 ± 1.3	
2003-12a	0:43:04.73	5.38	2992.3			mrg (EPIC)	213	<0.6	
	41:12:21.9					5925 (HRC-I)	353	<3.7	
						5926m (HRC-I)	374	<5.0	
						5927m(HRC-I)	406	<5.0	
						5928 (HRC-I)	430	<3.1	
2003-12b	0:42:54.14	2.07	2992.3			mrg (EPIC)	213	<0.3	
	41:15:12.2					5925 (HRC-I)	352	<2.6	
						5926m (HRC-I)	373	<2.4	
						5927m (HRC-I)	405	<1.6	
						5928 (HRC-I)	429	<2.2	
2003-12c	0:42:53.24	6.67	2994.2			mrg (EPIC)	211	<1.7	
	41:22:35.9					5925 (HRC-I)	351	<3.7	
						5926m (HRC-I)	372	<4.6	
						5927m (HRC-I)	404	<3.6	
						5928 (HRC-I)	428	<4.6	
2004-01b	0:42:41.19	0.71	3006.2			5925 (HRC-I)	339	<1.0	
	41:15:45.0					5926m (HRC-I)	360	<1.3	
						5927m (HRC-I)	392	<1.3	
						5928 (HRC-I)	416	<0.7	
2004-01a	0:43:08.65	4.60	3027.2			mrg (EPIC)	178	<0.8	
	41:15:35.4					5925 (HRC-I)	318	<2.4	
						5926m (HRC-I)	339	<2.9	
						5927m (HRC-I)	371	<2.9	
						5928 (HRC-I)	395	<3.2	
2004-03a	0:42:36.21	1.61	3068.3[<]			mrg (EPIC)	137	<2.7	
	41:15:37.9					5925 (HRC-I)	278	<1.8	
						5926m (HRC-I)	299	<1.4	
						5927m (HRC-I)	331	<1.2	
						5928 (HRC-I)	355	<1.8	
2004-03b	0:43:06.72	5.92	3079.3			mrg (EPIC)	126	<0.7	
	41:11:58.5					5925 (HRC-I)	267	<2.5	
						5926m (HRC-I)	288	<2.2	
						5927m (HRC-I)	320	<2.3	
						5928 (HRC-I)	344	<2.1	
2004-05b	0:42:37.04	2.16	3143.6			mrg (EPIC)	62	<0.9	
	41:14:28.5					5925 (HRC-I)	202	<1.4	
						5926m (HRC-I)	223	6.4 ± 0.9	
						5927m (HRC-I)	255	11.3 ± 1.2	
				J004237.0+411428	0.6	5928 (HRC-I)	279	19.4 ± 1.5	
2004-05a	0:42:37.55	6.01	3144.6			mrg (EPIC)	61	<1.0	
	41:10:16.4					5925 (HRC-I)	201	<3.8	
						5926m (HRC-I)	222	<2.5	
						5927m (HRC-I)	254	<3.1	
						5928 (HRC-I)	278	<2.8	
2004-05c	0:43:04.04	8.43	3145.6			mrg (EPIC)	61	<0.6	
	41:23:42.6					5925 (HRC-I)	200	<4.6	
						5926m (HRC-I)	221	<4.6	
						5927m (HRC-I)	253	<6.4	
						5928 (HRC-I)	277	<3.6	

Table 7. continued.

Optical nova candidate				X-ray measurements					
Name M31N	RA (h:m:s)[a] Dec (d:m:s)[a]	Offset[b] (′)	JD[c] 2 450 000+	Source name[d]	D (″)	Observation[e] ID	ΔT^f (d)	L_X^g	Comment
2004-06a	0:42:22.31	4.78	3164.5			4719 (ACIS-I)	40	<7.3	
	41:13:44.9					mrg (EPIC)	41	<0.7	
						4720 (ACIS-I)	87	10.2 ± 4.2	
						4721 (ACIS-I)	119	62.1 ± 9.0	SSS
						4722 (ACIS-I)	145	47.1 ± 8.3	
						4723 (ACIS-I)	180	<5.4	
				J004222.3+411345	1.0	5925 (HRC-I)	181	16.2 ± 1.5	
						5926m (HRC-I)	202	2.8 ± 0.8	
						5927m (HRC-I)	234	<3.1	
						5928 (HRC-I)	258	<2.6	
2004-06b	0:42:41.30	2.15	3178.5			mrg (EPIC)	27	<0.2	
	41:14:04.2					5925 (HRC-I)	168	<1.0	
						5926m (HRC-I)	189	<1.1	
						5927m (HRC-I)	221	<0.8	
						5928 (HRC-I)	245	<0.9	
2004-06c	0:42:49.02	3.28	3181.5			mrg (EPIC)	24	<1.0	
	41:19:17.8			J004249.0+411918	0.9	5925 (HRC-I)	165	33.9 ± 2.0	SSS (ACIS-I)
						5926m (HRC-I)	186	26.9 ± 1.9	
						5927m (HRC-I)	218	17.8 ± 1.5	
						5928 (HRC-I)	242	9.1 ± 1.2	
2004-07a	0:42:43.88	1.44	3181.5			mrg (EPIC)	24	<0.8	
	41:17:35.0					5925 (HRC-I)	165	<0.7	
						5926m (HRC-I)	186	<0.9	
						5927m (HRC-I)	218	<1.0	
						5928 (HRC-I)	242	<0.6	
2004-08a	0:42:20.62	4.45	3220.5[<]			4719 (ACIS-I)	–15	<4.0	
	41:16:09.5					4720 (ACIS-I)	32	<13.8	
				J004220.7+411608	1.8	4721 (ACIS-I)	64	51.9 ± 8.2	SSS
						4722 (ACIS-I)	90	<4.0	
						4723 (ACIS-I)	125	<6.2	
						5925 (HRC-I)	126	<2.1	
						5926m (HRC-I)	147	<2.8	
						5927m (HRC-I)	179	<2.0	
						5928 (HRC-I)	203	<3.4	
2004-08b	0:43:26.84	8.01	3225.5[*]			5925 (HRC-I)	121	<9.2	
	41:16:40.8					5926m (HRC-I)	142	<12.2	
						5927m (HRC-I)	174	<10.5	
						5928 (HRC-I)	198	<7.8	
2004-08c	0:42:42.77	0.49	3239.5	J004242.7+411545	0.3	5925 (HRC-I)	107	9.3 ± 1.0	SSS (ACIS-I)
	41:15:44.7					5926m (HRC-I)	128	1.2 ± 0.4	
						5927m (HRC-I)	160	<1.6	
						5928 (HRC-I)	184	<0.7	
2004-09a	0:42:40.27	1.62	3251.5[*]			5925 (HRC-I)	95	<0.5	
	41:14:42.5					5926m (HRC-I)	116	<0.7	
						5927m (HRC-I)	148	<0.7	
						5928 (HRC-I)	172	<1.5	
2004-10a	0:42:51.84	1.42	3258.4			5925 (HRC-I)	88	<0.8	
	41:16:18.2					5926m (HRC-I)	109	<1.5	
						5927m (HRC-I)	141	<0.5	
						5928 (HRC-I)	165	<1.2	
2004-09b	0:42:44.45	0.04	3264.6			5925 (HRC-I)	82	<1.6	
	41:16:10.5					5926m (HRC-I)	103	<3.2	
						5927m (HRC-I)	135	<2.3	
						5928 (HRC-I)	159	<1.6	
2004-10b	0:42:47.24	0.60	3267.4			5925 (HRC-I)	79	<0.9	
	41:15:54.5					5926m (HRC-I)	100	<0.8	
						5927m (HRC-I)	132	<1.0	
						5928 (HRC-I)	156	<0.8	

Table 7. continued.

Optical nova candidate				X-ray measurements					
Name M31N	RA (h:m:s)[a] Dec (d:m:s)[a]	Offset[b] (′)	JD[c] 2 450 000+	Source name[d]	D (″)	Observation[e] ID	ΔT^f (d)	L_X^g	Comment
2004-11f	0:42:47.15	0.56	3311.8			4722 (ACIS-I)	–1	<67.2	recurrent?
	41:16:19.8					4723 (ACIS-I)	34	20.3 ± 5.0	
				J004247.1+411620	0.3	5925 (HRC-I)	35	353.3 ± 6.2	SSS (ACIS-I)
						5926m (HRC-I)	55	11.4 ± 1.2	
						5927m (HRC-I)	87	1.2 ± 0.6	
						5928 (HRC-I)	112	<2.0	
2004-11a	0:42:42.81	2.34	3315.3			5925 (HRC-I)	31	<1.4	
	41:18:27.8					5926m (HRC-I)	52	<1.1	
						5927m (HRC-I)	84	<2.5	
						5928 (HRC-I)	108	<1.9	
2004-11b	0:43:07.45	4.76	3315.3			5925 (HRC-I)	31	<3.5	
	41:18:04.6					5926m (HRC-I)	52	<4.2	
						5927m (HRC-I)	84	11.5 ± 1.4	
				J004307.4+411804	0.1	5928 (HRC-I)	108	16.2 ± 1.6	
2004-11g	0:42:52.48	2.41	3315.3	J004252.4+411800	0.3	5925 (HRC-I)	31	27.5 ± 1.8	SSS (ACIS-I)
	41:18:00.2					5926m (HRC-I)	52	82.1 ± 3.0	
						5927m (HRC-I)	84	5.9 ± 0.9	
						5928 (HRC-I)	108	2.6 ± 0.6	
2004-11c	0:42:32.29	3.99	3326.4			5925 (HRC-I)	20	<1.8	
	41:19:25.7					5926m (HRC-I)	41	<1.7	
						5927m (HRC-I)	73	<2.2	
						5928 (HRC-I)	99	<2.3	
2004-11d	0:42:45.46	0.46	3334.2			5925 (HRC-I)	12	<0.9	
	41:16:33.2					5926m (HRC-I)	33	<1.0	
						5927m (HRC-I)	65	<1.4	
						5928 (HRC-I)	89	<1.3	
2004-11e	0:43:31.85	11.01	3339.3			5925 (HRC-I)	7	<16.3	
	41:09:42.6					5926m (HRC-I)	28	<9.9	
				J004331.6+410943	1.9	5927m (HRC-I)	60	35.9 ± 4.0	
						5928 (HRC-I)	84	9.1 ± 3.5	
2005-01a	0:42:28.39	3.03	3378.3*			5926m (HRC-I)	–11	<1.3	
	41:16:36.1					5927m (HRC-I)	21	<1.3	
						5928 (HRC-I)	45	<1.6	
2005-02a	0:42:52.79	2.30	3420.3			5927m (HRC-I)	–21	<1.5	
	41:14:28.9					5928 (HRC-I)	3	<1.5	

Notes: [a] RA, Dec are given in J2000.0; [b] projected distance from M 31 nucleus position ($RA_{J2000} = 00^h42^m44\overset{s}{.}324$, $\delta_{J2000} = +41°16'08\overset{''}{.}53$; Crane et al. 1992); [c] * indicates well defined start date of optical outburst, < outburst start before, else badly defined (see text); [d] full source names are CXOM31 Jhhmmss.s+ddmmss; [e] for XMM-Newton "mrg" indicate the merged EPIC data of ObsID 0202230201, 0202230401, and 0202230501; for *Chandra* we give ObsID and camera used (see text). 5926m indicate the merged data of ObsIDs 6177 and 5926, 5927m those of 6202 and 5927; [f] time after observed start of optical outburst; [g] un-absorbed luminosity in 0.2–1.0 keV band assuming a 50 eV black body spectrum with Galactic absorption, upper limits are 3σ.

name of the source (5), distance D between X-ray and optical position (6), observation number (7), days since optical nova outburst (8), X-ray luminosity in the 0.2−1.0 keV band as described above (9), and comments like reference for detection, nova type, and SSS classification (10). For novae close to the M 31 center we only give *Chandra* fluxes and upper limits as XMM-Newton in most cases can not resolve the sources from bright nearby sources and diffuse emission.

From the eleven novae from the PFF2005 list in Table 6, seven were no longer X-ray active in 2004. Due to the long gap in X-ray observations to the M 31 center that were sensitive to detect supersoft X-ray emission, the time of the end of the X-ray activity of these novae is not well constrained. For three of the optical novae in the table we give slightly improved optical positions and/or time of start of optical outburst compared to PFF2005 (M31N 2000-08a, M31N 2000-08d, M31N 2002-01b). For the SSS [PFH2005] 191 we now give the parameters for the new nova identification of Smirnova & Alksnis (2006) showing that the nova was already detected as a bright SSS 84 days after the optical outburst.

Four of the novae from the PFF2005 list (Nova M31N 1995-09b, M31N 1995-11c, M31N 1996-08b, M31N 2000-07a) are still detected in 2004. Nova M31N 1995-09b has dropped in brightness by more than a factor of 10 since the last detection in January 2002. Merging all 2004/5 HRC-I observations, it is detected with a significance of ~3σ 9.3 years after the optical outburst. The X-ray brightness of nova M31N 1995-11c has dropped by about a factor of three since the last detection in June 2002, however, is clearly visible in all XMM-Newton EPIC and *Chandra* HRC-I observations 2004/5, now 9.2 years after the optical outburst. Nova M31N 1996-08b, now 8.5 years after the optical outburst, stayed at the same X-ray brightness in 2004/5 or even slightly increased in brightness. The start of the SSS phase for nova M31N 2000-07a was constrained to

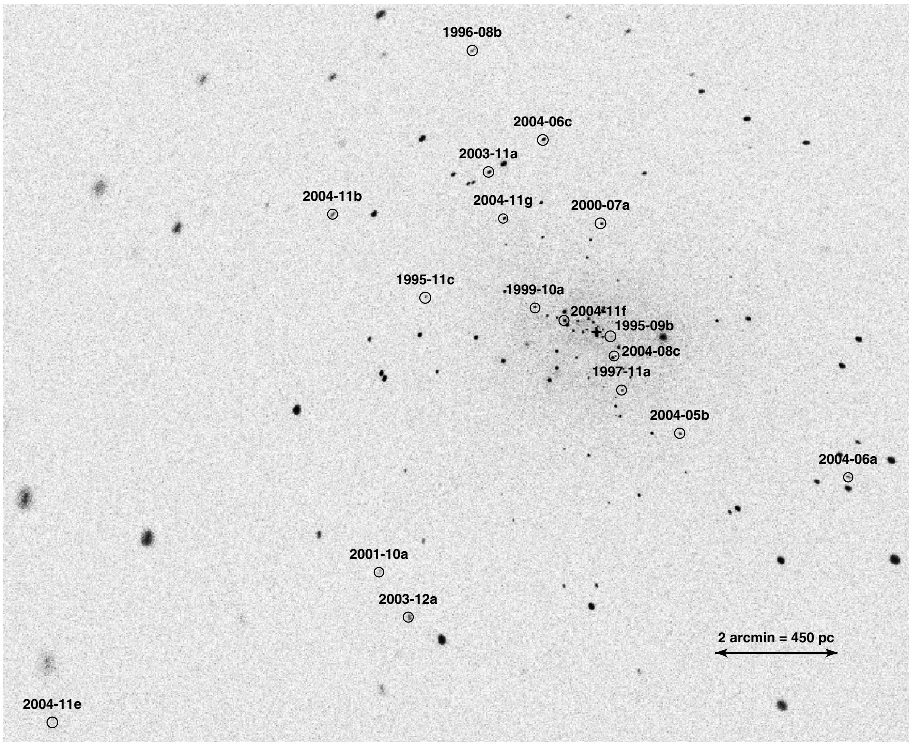

Fig. 3. Part of the merged *Chandra* HRC-I image of observations 5925, 6177, 5926, 6202, 5927, and 5928. Circles with 5″ radius indicate positions of optical novae detected in these HRC-I observations (see Tables 6 and 7). Nova names are given in CBAT nomenclature omitting the M31N prefix. The cross between the novae M31N 1995-09b and M31N 2004-11f indicates the M 31 center, the aim point of the observations.

154−170 days after the optical nova outburst. It is detected at similar X-ray brightness in 2004/5, more than 4.5 yr after the optical outburst.

We investigated for which of these novae we could compare the X-ray spectrum in 2004 to earlier spectra. For M31N 1995-09b, M31N 1995-11c and M31N 1996-08b, the number of counts above background is too low for detailed spectral fitting. However, for M31N 2000-07a, we collected in total about 900 source counts with the EPIC PN detector from ObsIDs 0202230201, 0202230301, 0202230401, 0202230501 which allowed spectral fitting and comparison to the spectral parameters derived for June 2001 and January 2002. In contrast to PFF2005, we use for this comparison just the EPIC PN detector due to its stable low energy response with time. We only rejected times of strong background flares in the (0.2−1.0) keV band to derive spectra for the July 2004 observations. In this way, significantly more time of the observations was usable than for the source detection procedures for which images with low background in all bands were needed (see Table 3). The spectra of the July 2004 observations were binned to contain at least 20 counts per bin and simultaneously fitted by an absorbed (tbabs in XSPEC, Wilms et al. 2000) blackbody model. June 2001 and January 2002 data were analyzed in the same way. Confidence contours for absorption column density and blackbody temperature are shown in Fig. 4. If we assume that the supersoft emission originates from the surface of a WD in M 31, fit results with $N_{\rm H}$ below the Galactic foreground and also results leading to bolometric luminosities above the Eddington luminosity of a WD can be excluded (at maximum 3.5×10^{38} erg s^{-1} for a WD with a mass at the Chandrasekhar limit, i.e. 1.4 $M_{\odot}$, and He-rich atmosphere, see e.g. Lewin et al. 1993).

The three novae counterparts that were not yet in the SSS state during the observations analyzed by PFF2005 (M31N 1997-11a, M31N 1999-10a, M31N 2001-10a) will be discussed in more detail in the following sub-sections.

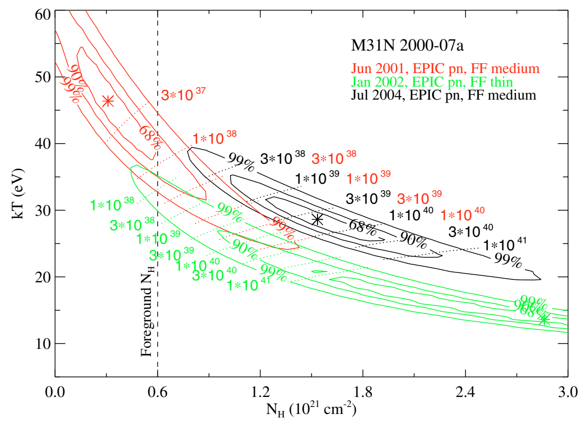

Fig. 4. Column density – temperature confidence contours inferred from the absorbed black body model fit to the XMM-Newton EPIC PN spectra of M31N 2000-07a. The formal best fit parameters are indicated by stars. Also drawn are lines of constant bolometric luminosity (in erg s^{-1}) for a distance of 780 kpc. The vertical dashed line indicates the Galactic foreground absorption in the direction of M 31. Contours for the observations in June 2001, January 2002 and July 2004 are coded in dark and light grey and black (see the electronic edition of the Journal for a color version of this figure).

4.1.1. Nova M31N 1997-11a

This nova candidate was reported by Rector et al. (1999, hereafter RJC99) from one Hα image on November 18, 1997. The object is also reported by Shafter & Irby (2001, hereafter SI2001) as nova 1997-07 from one Hα image on November 2, 1997. The nova was detected in the WeCAPP program as N1997-03 in the R band on November 1, 1997 and in the I band one day later. According to SI2001 the nova coincides in position with nova M31N 1982-08b and is therefore classified as recurrent nova ($\Delta T \sim 15$ yr). In X-rays, a counterpart was first

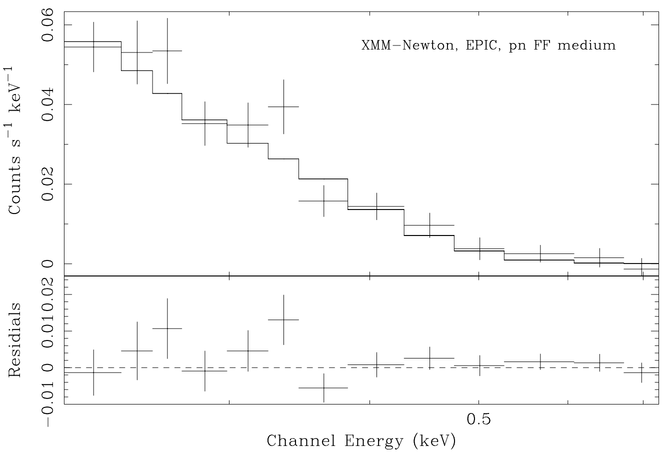

Fig. 5. Combined XMM-Newton EPIC PN spectrum of nova M31N 1999-10a. The absorbed black body fit to the data (see Sect. 4.1.2) is shown in the *upper panel*.

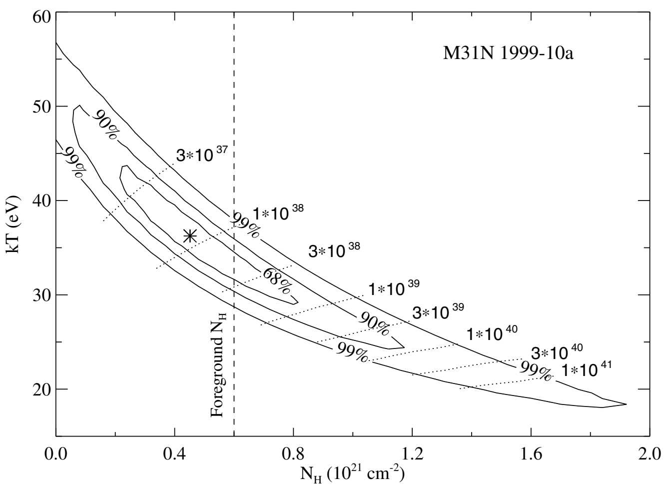

Fig. 6. Column density–temperature confidence contours inferred from the fit to the XMM-Newton EPIC PN spectra of M31N 1999-10a (see Fig. 5). The formal best fit parameters are indicated by stars. Also drawn are lines of constant bolometric luminosity and for the Galactic foreground absorption (see Fig. 4).

detected in the *Chandra* HRC-I observation 5925 about 7.1 years after the last reported optical outburst. The source is detected throughout HRC-I observation 5928. As it is rather faint the upper limit from the *Chandra* ACIS-I observation 4723 only leads to an ACIS-I/HRC-I count rate factor less than 1.3. This does not significantly constrain the X-ray spectrum. We therefore can not decide if it is a SSS.

4.1.2. Nova M31N 1999-10a

This nova candidate was reported by Filippenko et al. (1999, hereafter FCL99). FCL99 constrain the date of outburst to within a day (October 2, 1999) and confirmed the nova identification with an optical spectrum. An X-ray counterpart was detected in the XMM-Newton observations in July 2004, 4.8 years after the optical outburst. From the X-ray hardness ratios, the source can be classified as SSS. It stayed X-ray active till end of February 2005.

An X-ray spectrum was obtained from XMM-Newton EPIC PN ObsIDs 0202230201, 0202230301, 0202230401, 0202230501 (giving in total ~540 counts from the source). The spectra of the four observations were again (see description for M31N 2000-07a) simultaneously fitted by an absorbed blackbody model giving a best fit of $N_{\rm H} = \left(4^{+8}_{-4}\right) \times 10^{20}\,{\rm cm}^{-2}$ and $kT = (36 \pm 13)$ eV. For plotting, the four spectra were summed to one spectrum (see Fig. 5). To sum them up, we used the binning of the spectrum of 0202230201. Confidence contours for absorption column density and blackbody temperature are shown in Fig. 6.

4.1.3. Nova M31N 2001-10a

This nova candidate was first reported by Li (2001) and spectroscopically confirmed as nova in M 31 by Filippenko & Chornock (2001) with strong Balmer and Fe II emission lines. Light curves identifying the nova as moderately fast, are reported from the POINT-AGAPE microlensing survey (An et al. 2004; Darnley et al. 2004) and from the Nainital microlensing survey (Joshi et al. 2004). It is catalogued as N2001-13 by WeCAPP with a well defined position and date of outburst.

In X-rays, a counterpart was first detected in the *Chandra* HRC-I observation 5925 about 3.2 years after the optical outburst. The source is detected throughout HRC-I observation 5928. As it is rather faint, the upper limit from the *Chandra* ACIS-I observation 4723 only leads to an ACIS-I/HRC-I count rate factor less than 2.4. This does not constrain the X-ray spectrum. We therefore can not decide if the source has a supersoft spectrum.

4.2. Nova candidates detected in 2004/2005 within about a year after outburst

We searched for X-ray emission from nova candidates detected in 2004/2005 within about a year after outburst. We determined count rates and upper limits for the HRC-I observations and XMM-Newton observations. These results are given in Table 7 using the same layout as for Table 6 (see above). We also give count rates and upper limits for the ACIS-I observations after nova outburst if a counterpart is detected in at least one ACIS-I observation. 34 novae have been reported in the covered field with optical outburst between November 2003 and before the last X-ray observation.

Figure 7 shows the corresponding *Chandra* HRC-I (and ACIS-I) light curves plotting un-absorbed X-ray luminosities in the 0.2−1 keV band (assuming a 50 eV black body spectrum with Galactic absorption) against time after optical nova outburst. We included light curves of detected nova counterparts and non-detections plotting for each nova data points with 1σ errors connected by a line. Zero levels for the individual light curves are also given. The light curves have been shifted to avoid overlaps. For better visibility light curves of detected candidates are indicated by solid or dashed lines, not detected novae by dotted lines.

Two nova candidates are excluded from the list. The first is M31N 2004-12a, which exploded close to the bright persistent source [PFH2005] 269 corresponding to CXOM31 J004238.2+411000 (K2002) or r3-36 (KGP2002) at an offset of 6$'$.9 from the M 31 center. Due to the far off-axis distance X-ray emission from the nova – if any – could not be separated from emission from the bright source. The second is M31N 2004-02a. As discussed in Sect. 2, M31N 2004-02a and M31N 2004-11f are only separated by ~2$''$. We detect X-ray

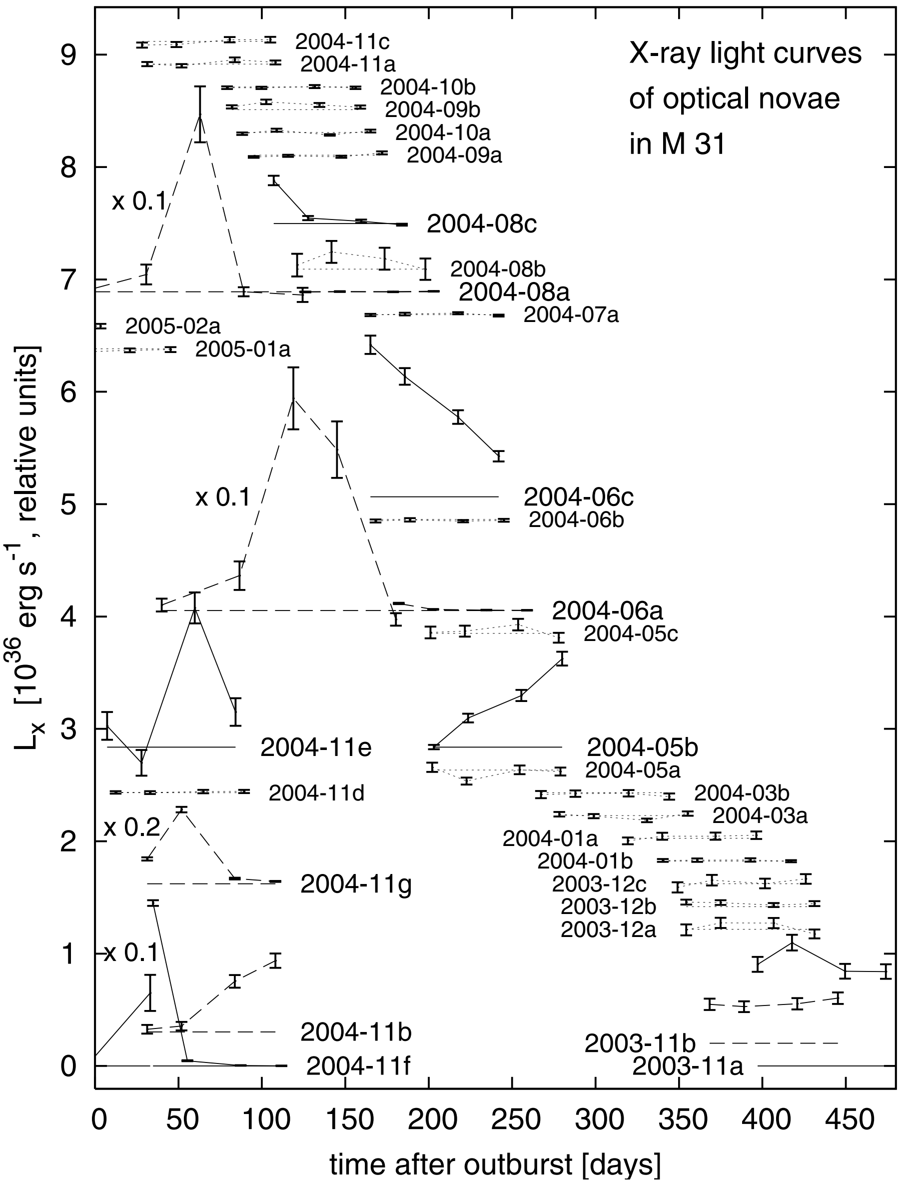

Fig. 7. X-ray light curves of optical nova counterparts observed by the *Chandra* HRC-I and ACIS-I instruments during 2004/5 within about a year after outburst. Detected sources are indicated by solid or dashed lines, not detected novae by dotted lines. Zero level for the individual light curves are indicated and have been shifted for clarity. They are labeled with the nova names (following CBAT nomenclature) using a bigger font for detected novae (see text and Table 7).

emission from within 0.″3 from the position of M31N 2004-11f and therefore connect the emission to this nova candidate and not to M31N 2004-02a (see Table 7).

From the remaining 32 nova candidates, eleven have counterparts in X-rays detected as transient sources till end of February 2005. These nova candidates will be discussed in more detail in the following subsections. This leaves 21 nova candidates that have not been detected in X-rays. Possible reasons for the lack of detection will be discussed later.

4.2.1. Nova M31N 2003-11a

This nova candidate was first reported by Hornoch (2003b). Fiaschi et al. (2003) constrained the date of outburst and WeCAPP (N2003-12) provided accurate positioning. In X-rays a counterpart was first detected in the *Chandra* HRC-I observation 5925 about 400 days after the optical outburst. The source is detected throughout HRC-I observation 5928. The upper limit from the *Chandra* ACIS-I observation 4723 leads to an ACIS-I/HRC-I count rate factor less than 0.6. This clearly indicates that the source had a supersoft spectrum.

4.2.2. Nova M31N 2003-11b

This nova candidate was first reported by Fiaschi et al. (2003). Mobberley et al. (2004) constrained the date of outburst and WeCAPP (N2003-13) provided accurate positioning. In X-rays a counterpart was first detected in the *Chandra* HRC-I observation 5925 about 370 days after the optical outburst. The source is detected throughout HRC-I observation 5928. The upper limit from the *Chandra* ACIS-I observation 4723 leads to an ACIS-I/HRC-I count rate factor less than 0.9. This indicates that the source had a soft spectrum.

4.2.3. Nova M31N 2004-05b

This nova candidate was detected by Hornoch and Kušnirák (see Appendix B, No. 13) after the M 31 visibility window opened again in May 2004. Therefore the time of optical outburst is not well defined. In X-rays a counterpart was first detected in the *Chandra* HRC-I observation 5926 m about 220 days after the optical outburst with a linear increase in brightness during the following two observations (till day 280 after optical outburst). The source is not detected during *Chandra* HRC-I observation 5925. We therefore can not constrain the X-ray spectrum using the ACIS-I/HRC-I count rate ratios.

4.2.4. Nova M31N 2004-06a

This nova candidate was detected by Hornoch (see Appendix B, No. 15). The optical outburst could have happened at most 8 days before detection. In X-rays a source coincident with the nova position was first detected 87 days after the optical outburst. The X-rays reached a maximum around day 120 when the source was detected as bright SSS (black body temperature around 70 eV, see below). About 200 days after outburst the SSS phase ended.

Chandra ACIS-I spectra were obtained for this nova from observations 4721 and 4722. Although in total only 84 counts were collected, their distribution at energies below ~800 eV allows to derive constraints from the X-ray spectra. The spectra were binned to contain at least 10 counts per bin and simultaneously fit by an absorbed (tbabs in XSPEC, Wilms et al. 2000) blackbody model. Confidence contours for absorption column density and blackbody temperature are shown in Fig. 8.

4.2.5. Nova M31N 2004-06c

This nova candidate was detected by Hornoch (see Appendix B, No. 17). The start of the optical outburst is only defined to about 2 weeks. In X-rays a counterpart was detected during the *Chandra* HRC-I observations 5925 to 5928. The X-ray intensity decreased linearly by a factor 3 to 4 from day 165 to 242. The upper limit from the *Chandra* ACIS-I observation 4723 leads to an ACIS-I/HRC-I count rate factor less than 0.4. This clearly indicates that the source had a supersoft spectrum.

4.2.6. Nova M31N 2004-08a

This candidate for a fast nova was detected by Hornoch and Šarounová (see Appendix B, No. 19). The optical outburst could have happened at most 3 days before detection. In X-rays a counterpart was only significantly detected 64 days after the optical outburst during *Chandra* ACIS-I observation 4721. A *Chandra* ACIS-I spectrum with 42 counts was accumulated from this observation. The analysis was performed similar to the case of M31N 2004-06a and the NH-kT contours are plotted in Fig. 8. The spectrum indicates a SSS with a black body spectrum of 80 eV or less. The source was not visible in ACIS-I observations 30 days earlier or later.

4.2.7. Nova M31N 2004-08c

This nova candidate was first reported by Tzenev et al. (2004). The time of the optical outburst is not well defined. WeCAPP (N2004-04) provided accurate positioning. In X-rays a counterpart was detected 107 days after the optical outburst in the *Chandra* HRC-I observation 5925 and was barely visible 20 days later. The upper limit from the *Chandra* ACIS-I observation 4723 leads to an ACIS-I/HRC-I count rate factor less than 0.4. This clearly indicates that the source had a supersoft spectrum.

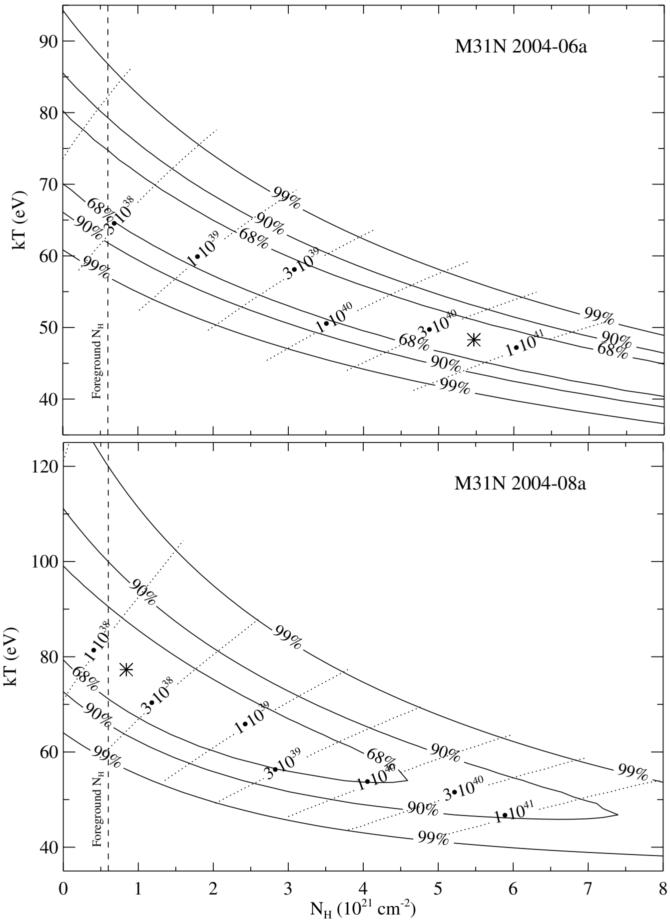

Fig. 8. Column density – temperature confidence contours inferred from the fit to the ACIS-I spectra of M31N 2004-06a obtained from *Chandra* ACIS-I observations 4721 and 4722 (*above*) and of M31N 2004-08a obtained from *Chandra* ACIS-I observations 4721 (*below*). The formal best fit parameters are indicated by stars. Also drawn are lines of constant bolometric luminosity and for the Galactic foreground absorption (see Fig. 4).

4.2.8. Nova M31N 2004-11f

The optical detection of this nova candidate was discussed in Sect. 2. The optical outburst could have happened at most 7 days before the HST detection. In X-rays a counterpart was detected 34 days after the optical outburst in the *Chandra* ACIS-I observation 4723. The count rate from the *Chandra* ACIS-I observation 4723 leads to an ACIS-I/HRC-I count rate factor of 0.07. This clearly indicates that the source had a supersoft spectrum. The source intensity dropped within 20 days by a factor of more than 30. The X-ray source was no longer detected after 90 days.

Following the discussion in Sect. 2 the nova may well be a recurrent nova ($\Delta T \sim 20.3$ yr).

4.2.9. Nova M31N 2004-11b

This nova candidate was detected by Hornoch (see Appendix B, No. 24). The optical outburst could have happened at most 11 days before detection taking into account the last WeCAPP non detection before the Hornoch discovery. WeCAPP (N2004-09) in addition provided accurate positioning. Filippenko et al.[1] spectroscopically confirmed the variable as nova in M 31. In X-rays a counterpart was detected 84 days after the optical outburst in the *Chandra* HRC-I observations 5927 m and increased in brightness by a factor of 1.5 within the 24 days to observation 5928. The source is not detected during *Chandra* HRC-I observation 5925. We therefore can not constrain the X-ray spectrum using the ACIS-I/HRC-I count rate ratios.

4.2.10. Nova M31N 2004-11g

The optical detection of this nova candidate was discussed in Sect. 2. The optical outburst could have happened at most 11 days before the detection. In X-rays a counterpart was detected 31 days after the optical outburst in the *Chandra* HRC-I observation 5925, increased in brightness by a factor of ~3 to observation 5926 m 21 days later. After a drop in intensity by a factor of more than 10 within 32 days it was barely visible in observations 5927 m and 5928. The upper limit from the *Chandra* ACIS-I observation 4723 leads to an ACIS-I/HRC-I count rate factor less than 0.2. This clearly indicates that the source had a supersoft spectrum.

4.2.11. Nova M31N 2004-11e

This nova candidate was detected by Hornoch (see Appendix B, No. 27) after a gap in observations of 18 days. In X-rays a counterpart was detected 31 days after the optical outburst in the *Chandra* HRC-I observation 5927 m. It had already dropped in intensity 24 days later by a factor of more than 3. The source is not detected during *Chandra* HRC-I observation 5925. We therefore can not constrain the X-ray spectrum using the ACIS-I/HRC-I count rate ratios.

5. Discussion and conclusions

Optical novae have recently been identified as the major class of supersoft X-ray sources in M 31 based on ROSAT and early XMM-Newton and *Chandra* observations (PFF2005). In this second paper on our program to systematically search for X-ray emission from optical novae in M 31 we concentrate on archival *Chandra* observations to the M 31 center. While in the first paper the sampling was mainly based on four XMM-Newton observations separated by half a year (together with ROSAT and some *Chandra* observations), we here concentrate on four HRC-I observations with a 20 to 30 day spacing obtained from December 2004 to February 2005. Five ACIS-I observations with a monthly spacing (July to December 2004), the last one 1.7 days before the time of the first HRC-I observation, were of great importance to extend the time coverage, even when the ACIS-I CCDs are only sensitive to detect extremely bright nova counterparts with a supersoft spectrum or counterparts that have spectra at the high temperature end for SSS. We also included in the analysis four XMM-Newton observations of the M 31 center region obtained within four days in July 2004. In this way we were able to cover a large enough time base to detect not only several nova counterparts with long duration SSS phase but also a significant number of nova counterparts with short SSS phase (SSS turn-off <100 d after outburst).

For comparison with the X-ray data we created a catalogue of optical novae in M 31 based on our own nova search programs and on all novae reported in the literature. We collected all known properties and named the novae consistently following the CBAT scheme.

Some nova counterparts are still detected in X-rays several thousand days after the optical nova outburst. The three extremes are M31N 1995-09b, M31N 1995-11c and M31N 1996-08b detected 3383, 3373 and 3115 days (i.e. 9.3, 9.2 and 8.5 years) after outburst, respectively. This can be compared to nova counterparts in the Galaxy and Magellanic Clouds with long SSS states: nova V723 Cas detected as SSS more than 11 years after outburst (Ness et al. 2006); GQ Mus, SSS for less than 9 years (Ögelman et al. 1993); nova LMC 1995, SSS for less than 8 years (see Orio et al. 2003; Orio 2004).

Inspecting Fig. 7, two novae show a linear rise in X-ray flux (M31N 2004-05b, M31N 2004-11b) and one a linear decay (M31N 2004-06c). However, more resolved X-ray light curves are needed to see if this behavior is common for many novae and deserves further modeling. One nova counterpart is detected to turn on as SSS 50 d, another 200 d after the optical nova outburst. Three nova counterparts unexpectedly showed short X-ray outbursts starting within 50 d after the optical outburst and lasting only two to three months. From Fig. 7 it is clear that specifically for novae with short SSS states, the observations in the archive are not sampling the light curves with sufficient resolution and sensitivity to really allow us to resolve the outbursts for detailed modeling. For such a task, dedicated observations are urgently needed. Nevertheless, many interesting results can already be deduced from the available observations.

In Table 8 we combine optical and X-ray properties of the X-ray detected novae presented in Tables 6 and 7 and as derived parameters the ejected and burned masses. The optical information includes accuracy with which the outburst date is known, nova confirmation by optical spectra, a flag for recurrent novae, observed brightness in outburst and the fastness parameter t_{2R}. From the X-ray measurements we give start of SSS phase, turn-off of SSS phase (defined as factor of 10 decrease from maximum X-ray luminosity), the maximum X-ray luminosity and the allowed (3σ) temperature range from a black body fit. M31N 1994-09a, M31N 1997-08b and M31N 2002-01b are not included as start and turn-off time of the SSS state are not well determined and no useful mass limits can be given.

The un-absorbed X-ray luminosity in the 0.2−1.0 keV band during maximum is rather uncertain and the tabulated values have to be taken with care. For nova counterparts with a short SSS phase, the time of maximum X-ray brightness may not be covered by the observations. Also, X-ray brightnesses calculated assuming a 50 eV black body spectrum with Galactic absorption are very uncertain. As the spectral fits to several novae show, the surface temperature can vary significantly from nova to nova (see discussion below) which would alter the un-absorbed X-ray luminosity by factors of 10 or more. Also additional absorption within M 31 may enhance the computed un-absorbed X-ray luminosities.

The ejected mass in the nova outburst can be approximately determined from the start date of the SSS phase. The decrease of the optical thickness of the expanding ejecta is responsible for the rise in the X-ray light curve of the post-outburst novae, as shown for V1974 Cyg (Shore et al. 1996; Krautter et al. 1996). Assuming the material ejected by the nova explosion

[1] See http://cfa-www.harvard.edu/iau/CBAT_M31.html

Table 8. Observed and derived parameters of X-ray detected optical novae in M 31.

Optical measurements				X-ray measurements				Derived parameters	
Name[a] M31N	R[b]	Brightness[c] (mag Filter)	t_{2R} (d)	SSS phase Start (d)	SSS phase Turn-off (d)	L_X^d	kT_{BB}^e (eV)	Ejected mass (10^{-5} $M_\odot$)	Burned mass (10^{-6} $M_\odot$)
1995-09b		15.6 Hα		–	2327–3383	16.1		–	3.9–5.7
1995-11c		16.3 Hα		–	>3373	13.8		–	>5.7
1996-08b	r	16.1 Hα		1782–1880	>3115	5.6		330–370	>5.2
1997-11a	r	18.0 R		1461–2593	>2670	4.4		220–700	>4.5
1998-06a	r	16.3 Hα		–	1310–2235	1.7		–	2.2–3.7
1999-10a		17.5 w		760–1751	>1969	21.2	30–38	61–320	>3.3
2000-08a		18.6 R		203–253	494–1627	16.8		4.3–6.7	0.83–2.7
2000-07a*		16.8 R	22.4	154–170	>1668	13.5	28–37	2.5–3.0	>2.8
2001-08d*		16.7 R	11.8	<63	<1055	0.7		<0.42	<1.8
2001-10a*+		17.0 R	39.3	1019–1158	>1235	5.2		110–140	>2.1
2001-10f		16.6 B		17–84	<1009	37.0		0.03–0.74	<1.7
2003-11a*		16.9 R		256–396	>473	27.6		6.9–16	>0.79
2003-11b*		17.4 R	42.2	227–367	>444	10.4		5.4–14	>0.75
2004-05b		17.2 R	49.7	202–223	>279	19.4		4.3–5.2	>0.47
2004-06a		17.2 R	19.7	41–87	145–180	62.1	63–87	0.2–0.8	0.24–0.30
2004-06c		17.1 R	10.9	24–165	>242	33.9		0.6–2.9	>0.41
2004-08a		17.4 R		32–64	64–90	51.9	60–120	0.1–0.4	0.11–0.15
2004-08c		18.7 R	50.3	<107	128–160	9.3		<1.2	0.21–0.27
2004-11f	?	17.9 R	28.4	<34	35–55	353.3		<0.1	0.06–0.09
2004-11b+		16.6 R	32.0	52–84	>108	16.2		0.3–0.7	>0.18
2004-11g		17.9 R	28.4	<31	52–84	82.1		<0.1	0.09–0.14
2004-11e		17.6 R	34.6	28–60	>84	35.9		0.08–0.4	>0.14

Notes: [a] * Indicates that the date of outburst is well defined, + indicates novae confirmed by optical spectra; [b] flag for recurrent novae: "r" indicates recurrent nova candidates, "?" the recurrent candidate discussed in Sect. 2; [c] "w" indicates without filter; [d] un-absorbed luminosity in 0.2–1.0 keV band in units of 10^{36} erg s^{-1} during observed maximum X-ray brightness assuming a 50 eV black body spectrum with Galactic absorption; [e] allowed black body temperature range from spectral fit.

to form a spherical homogeneous shell expanding at constant velocity v, the hydrogen mass density of the shell will evolve in time t like $\rho = \frac{M_H^{ej}}{\frac{4}{3}\pi v^3 t^3}$ where M_H^{ej} is the ejected hydrogen mass (Krautter et al. 1996). Assuming an homogeneous density, the column density of hydrogen will evolve with time like $N_H(\mathrm{cm}^{-2}) = \frac{M_H^{ej}}{\frac{4}{3}\pi m_H v^2 t^2}$, where $m_H = 1.673 \times 10^{-24}$ g is the mass of the hydrogen atom. Assuming typical values for the expansion velocity (2000 km s^{-1}) and that the SSS turns on when the absorbing hydrogen column density decreases to $\sim 10^{21}$ cm^{-2}, we determine the ejected mass for each nova in Table 8. Typical ejected masses are up to a few times 10^{-5} $M_\odot$. These estimates can be improved for novae with measured outflow velocities. Unfortunately, only for one nova in our sample an expansion velocity was derived from an optical spectrum (2500 km s^{-1} for M31N 2004-11b)[2]. For the novae that have a SSS phase starting more than one year after the optical outburst, the ejected masses are unrealistically large. Some of them are proven recurrent novae (M31N 1996-08b, M31N 1997-11a; see Table A.1), and thus the ejected mass calculated from the SSS turn-on time is meaningless. In the other cases of delayed SSS, it may be RN or SSS phases that started again on the hot post-novae WD surface without an optical outburst (see Starrfield et al. 2004). For some of the novae we can not constrain the start times of the SSS state in a useful manner and consequently no ejected mass is estimated.

The turn-off time of the SSS phase indicates directly the amount of hydrogen rich material burned on the WD surface, $M^{burn} = \frac{L\Delta t}{X_H \epsilon}$, where L is the bolometric luminosity, Δt is the duration of the SSS phase, X_H is the hydrogen fraction of the burned material and $\epsilon = 5.98 \times 10^{18}$ erg g^{-1}. We compute the burned mass during the SSS phase for each novae, assuming a bolometric luminosity of 3×10^4 $L_\odot$ and a hydrogen mass fraction $X_H = 0.5$. The values given in Table 8 correspond to the mass burned assuming that the hydrogen burning phase of a nova starts with the time of outburst and ends with the turn-off of the SSS phase. For most of the novae the burned mass is below a few times 10^{-6} $M_\odot$. For novae in which the SSS phase has not ended during our observations we only give lower limits for the burned mass. However, none of them is extraordinarily high. If in some novae the SSS phase (and also the hydrogen burning phase) should be delayed as proposed above, the burned mass estimates would just represent upper limits.

In spite of the uncertainties and the fact that for most novae we only obtain upper or lower limits, for the cases with constrained burned and ejected mass (i.e., novae M31N 2000-08a, M31N 2004-06a and M31N 2004-08a) the burned mass is about one order of magnitude smaller than the ejected mass. The burned masses are within the values expected from models of post-outburst novae with stable hydrogen burning envelopes (Sala & Hernanz 2005b; Tuchman & Truran 1998), while the ejected masses derived for M 31 novae are also in the ranges of the ejected masses predicted from hydrodynamical models of nova outbursts (José & Hernanz 1998). But without any information on the accreted mass and the degree of mixing of the accreted envelope with the degenerate core, we cannot draw a conclusion on the actual increase or decrease of the white dwarf mass and its long-term evolution.

[2] See Filippenko et al. at
http://cfa-www.harvard.edu/iau/CBAT_M31.html

As mentioned in Sect. 4.2, 21 of the 32 novae with optical outburst from November 2003 to February 2005 have not been detected in X-rays. This could have several reasons: (i) the novae could have very short SSS phases which are not covered by our X-ray sampling; (ii) the SSS phase of the novae ended before the X-ray observations in 2004; (iii) the SSS phase will only start after the X-ray observations in 2005; (iv) last but not least, the novae could not go through a SSS phase. From the above numbers it is however clear that more than 30% of the novae (and probably even many more) go through a X-ray SSS phase. This percentage is about a factor of two above the lower limit given by PFF2005 and corroborates their expectation that the fraction of novae with SSS phase may be significantly higher.

X-ray emission of eight of the 14 newly detected optical nova counterparts can be characterized as supersoft from hardness ratios and spectra or by comparing HRC-I count rates with ACIS-I count rates or upper limits. For four nova counterparts we were able to model the X-ray spectrum in greater detail. While the spectra of novae with longer SSS states have lower temperatures (M31N 2000-07a and M31N 1999-10a show a kT of about 30−35 eV), the novae with short SSS state seem to have significantly higher temperatures (M31N 2004-06a and M31N 2004-08a about 70−80 eV). This fits to the nova outburst behavior calculated by Hachisu & Kato (2006a) that was successfully applied to predict and model the X-ray light curve of the recurrent nova RS Oph (Hachisu & Kato 2006b; Hachisu et al. 2006), V1974 Cyg (Hachisu & Kato 2005), V693 CrA, V1668 Cyg, V351 Pup and OS And (Kato & Hachisu 2006). In these models novae with lower mass WDs show longer lasting SSS states with lower temperatures, novae with higher mass WDs show shorter SSS states with higher temperatures.

Based on these and earlier results we initiated an optical (photometry and spectroscopy) and X-ray monitoring program for novae in the central region of M 31. In this way we hope to get a better handle on the percentage of novae showing SSS states and novae with short SSS states.

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Online Material

Appendix A: Master catalog of novae detected in M 31

For cross-correlating with X-ray sources and searching for recurrent novae we created a catalogue of all historical optical novae detected in M 31. During this work we noticed that a homogeneous naming of all novae in M 31 is missing. After discussions with Nicolai Samus, who's group provided naming for some novae in the "General Catalogue of Variable Stars" (Samus et al. 2004) and Daniel Green from the Central Bureau for Astronomical Telegrams CBAT of the International Astronomical Union, we decided to extend the CBAT naming scheme to all optical novae and candidates in M 31 that have been reported in the literature and make the information available in Table A.1 (novae with outbursts before end of 2005) together with additional parameters and references (Table A.2) and in extended form via the Internet[3]. We intend to update the Internet pages regularly and encourage observers to provide input for historical and forthcoming optical novae in M 31. We will include photometric and spectroscopic data of optical novae and candidates in M 31 covering all wavelengths.

We combined the WeCAPP nova list (FBR2007) with novae from other microlensing surveys of M 31: the AGAPE survey (Ansari et al. 2004), the POINT-AGAPE PACN survey (An et al. 2004; Darnley et al. 2004), the Nainital Microlensing Survey (Joshi et al. 2004) and the survey by Tomaney & Crotts (1996). We added novae from IAU circulars, astronomical telegrams (ATel) and information bulletins on variable stars (IBVS) and novae and candidates on the "M 31 (Apparent) Novae Page" provided by the International Astronomical Union, Central Bureau for Astronomical Telegrams CBAT and the finding charts and information, collected by David Bishop ("Extragalactic Novae – 2003" and following years). We included novae from the Hα searches of Shafter & Irby (2001), Rector et al. (1999, nova and nova candidate lists[4]), Tomaney & Shafter (1992), Ciardullo et al. (1990, 1987, 1983). We added the lists by Sharov and colleagues (Sharov & Alksnis 1991, 1992a,b; Sharov 1993, 1994; Sharov & Alksnis 1994, 1995, 1996, 1997; Sharov et al. 1998; Sharov & Alksnis 1998; Sharov et al. 2000) and Rosino et al. (1989).

We also included all earlier catalogues: Rosino and colleagues (Rosino 1973, 1964; Grubissich & Rosino 1958, 1956; Rosino & Grubissich 1955), Börngen (1968), Moffat (1967), Baade & Swope (1965), Gaposchkin (1962), Baade & Arp (1964), Arp (1956), Stratton (1936), Mayall (1931), and of course the pioneering work of Hubble (1929).

In the work of Stratton (1936), only the year of the nova outburst is given. Baade & Arp (1964) for one nova explicitly give 1948 as the year of outburst for three novae we assumed 1945 as year of outburst. For all these novae for naming purposes we assumed outbursts on September 1 of the year. Nova positions in the earlier catalogues (based on optical images obtained with photographic plates) were often only determined to 0.1 arcmin or worse. Including these novae in searches for recurrent novae and correlations with X-ray sources is problematic as one might find many spurious identifications specifically in the central region of M 31 which is crowded with novae and X-ray sources. A re-analysis of these archival plates (digitization and position determination) is partly in progress or urgently should be done. Only then one will be able to fully exploit these important early data.

The M 31 nova catalogue in Table A.1 contains 719 optical novae and nova candidates with outbursts before end of 2005.

Appendix B: Discovery and optical photometry of novae in M 31 by Kamil Hornoch

An extensive nova search in the center area of M 31 is performed mostly based on images obtained with telescopes of the Lelekovice (350/1658 mm) and Ondřejov observatories (650/2342 mm) which are equipped with a SBIG ST-6V CCD camera with $18' \times 13'$ FOV at the Newton focus and an Apogee AP7p CCD camera, $19' \times 19'$ FOV at the primary focus, respectively, and both mainly use Kron-Cousins R filters. From Lelekovice, mostly two overlapping fields are imaged if weather and time permit, one with the center NE from the M 31 center and the second with the center SW from the M 31 center. Sometimes, also regions NW and SE of the center of galaxy are imaged. In almost every observing night the M 31 nucleus was covered. From Ondřejov, mostly just one field is imaged centered on the M 31 nucleus. In cases, when a nova more distant from the M 31 center was discovered, Ondřejov image positions were placed to also cover the nova (up to the time when it faded below the sensitivity limit).

Standard reduction procedures for CCD images were applied (bias, dark-frame, flat-field correction using the Munipack[5] or SIMS[6] programs). Reduced images are then added. The total exposure time is typically 10−20 min per field (typical exposure times of partial exposures from Ondřejov are 180 s, from Lelekovice 60 s). Gradient of the galaxy background of added images is flattened by median filter using SIMS. Last procedure is aperture photometry (using GAIA[7]) and astrometry (using APHOT, a synthetic aperture photometry and astrometry software developed by M. Velen and P. Pravec at the Ondřejov Observatory). Each suspected nova was checked by an inspection of all contributing images. The comparison stars were calibrated using Landolt fields and the "BVRI CCD photometry of 361 281 objects in the field of M 31" (Magnier et al. 1992). Aperture photometry is made by hand because there is necessity to determine level of background at the place of the nova. Typical photometric uncertainties are about 0.1−0.15 mag for the brighter novae increasing up to ~0.3 mag close to the detection limit (i.e. if the nova is faint or if its position is close to the M 31 center or if it is placed at a very non-uniform background). The values of uncertainties are similar for objects of 18 mag measured from Lelekovice as for objects about 19 mag when they are observed from Ondřejov. For astrometry we created (with the help of Miroslav Velen and Petr Pravec) a special catalog of fainter objects in the M 31 field derived from Ondřejov images corrected to the world coordinate system (WCS) with the help of stars from the UCAC2 catalog (Zacharias et al. 2004). Typically, 100−200 stars from this catalog can be used for WCS determination on Lelekovice or Ondřejov images. Mean residual of catalog positions are $0.2''-0.3''$ and derived nova positions mostly better than $1''$ and frequently better than $0.5''$ as comparison with positions of the same novae from larger telescopes show. With the help of the astrometric catalog we were able to obtain good positions also for images from the M 31 center

[3] See http://www.mpe.mpg.de/~m31novae/opt/m31/index.php

[4] available at http://www.noao.edu/outreach/rsbe/nova.html

[5] http://munipack.astronomy.cz/

[6] http://ccd.mii.cz/

[7] http://star-www.dur.ac.uk/~pdraper/gaia/gaia.html

Table B.1. Nova positions of novae measured by Kamil Hornoch on discovery images or on best images available at the time of announcement of discovery. Eight additional positions for novae Nos. 24, 25, 32, 33, 37 to 39, and 41 were measured on deep images with better signal to noise for novae and with better resolution compared to announcement images. Discoverers and references for the individual novae are given under columns “Dis.” and “Ref.”. For photometric data of individual novae see Table B.2.

No.	Name[a] M31N	RA J2000 (h:m:s)	Dec J2000 (+d:m:s)	Offset RA	Offset Dec	Outburst JD 2 450 000+	R (mag)	t_{2R} (d)	Dis.[b]	Refs.[c]
1	2002-08a	00:42:30.92	+41:06:13.1	152″ W	596″ S	2490.523	17.05	51.0 (52[d])	(a)	(1, 10)
2	2003-06b	00:43:36.17	+41:16:39.4	583″ E	30″ N	2815.507	16.7	7.0–40.6 (28[d])	(a)	(2)
3	2003-07b	00:42:15.81	+41:12:00.5	318″ W	252″ S	2835.488	16.9	16.6–23.3 (20[d])	(a)	(3)
4	2003-06d	00:42:41.10	+41:18:32.0	36″ W	144″ N	2840.531	18.5		(a)	(3)
5	2003-09b	00:42:46.72	+41:19:46.7	26″ E	219″ N	2913.335	17.0	52.7 (53[d])	(a)	(4, 11)
6	2003-08c	00:42:41.09	+41:16:16.3	37″ W	8″ N	2930.476	17.9		(b)	(11)
7	2003-11a	00:42:53.64	+41:18:45.9	105″ E	157″ N	2952.573	16.9		(a)	(5)
8	2003-12a	00:43:04.77	+41:12:23.0	231″ E	226″ S	2997.195	17.8	34.2 (35[d])	(a)	(6)
9	2004-01a	00:43:08.65	+41:15:35.4	274″ E	33″ S	3035.232	17.8	46.5–87.3 (48[d])	(a)	
10	2004-03a	00:42:36.21	+41:15:37.9	92″ W	31″ S	3068.267	17.3	11.0 (12[d])	(a)	
11	2004-03b	00:43:06.72	+41:11:58.5	253″ E	250″ S	3079.272	18.1		(a)	
12	2004-05a	00:42:37.55	+41:10:16.4	76″ W	352″ S	3144.560	17.0	19.4–28.2	(b)	
13	2004-05b	00:42:37.04	+41:14:28.5	82″ W	100″ S	3143.561	17.2	49.7	(b)	
14	2004-05c	00:43:04.04	+41:23:42.6	222″ E	454″ N	3145.563	18.4	36.4	(b)	
15	2004-06a	00:42:22.31	+41:13:44.9	248″ W	144″ S	3164.541	17.2	19.7	(a)	
16	2004-06b	00:42:41.30	+41:14:04.2	34″ W	124″ S	3178.503	17.8	45.0–47.7	(a)	
17	2004-06c	00:42:49.02	+41:19:17.8	53″ E	189″ N	3181.517	17.1	10.9	(a)	
18	2003-07a	00:42:02.93	+41:05:01.5	468″ W	667″ S	2847.480	17.6	<255.9	(d)	
19	2004-08a	00:42:20.62	+41:16:09.5	267″ W	1″ N	3220.474	17.4		(d)	
20	2004-08b	00:43:26.84	+41:16:40.8	479″ E	32″ N	3225.482	17.3	39.6–63.0	(b)	(7, 12)
21	2004-09a	00:42:40.25	+41:14:42.9	46″ W	86″ S	3251.518	17.5	23.8-31.5	(c)	(7, 12)
22	2004-10a	00:42:51.84	+41:16:18.2	84.7″ E	9.7″ N	3287.835	18.6		(f)	
23	2004-10b	00:42:47.24	+41:15:54.6	32.9″ E	13.9″ S	3288.805	18.6		(f)	
24	2004-11b	00:43:07.43	+41:18:04.4	260.4″ E	115.9″ N	3315.347	16.6	32.0	(a)	(13)
		00:43:07.46	+41:18:04.4							
25	2004-11a	00:42:42.76	+41:18:28.0	17.6″ W	139.5″ N	3315.347	16.5	11.7	(a)	(13)
		00:42:42.80	+41:18:28.0							
26	2004-11d	00:42:45.47	+41:16:33.1	12.9″ E	24.6″ N	3334.218	17.0	15.3	(a)	
27	2004-11e	00:43:31.85	+41:09:42.6	536.3″ E	385.9″ S	3339.296	17.6	34.6	(a)	
28	2004-12a	00:42:28.05	+41:09:55.6	183.6″ W	372.9″ S	3370.230	16.8	14.0–17.2	(a)	
29	2005-01a	00:42:28.38	+41:16:36.2	179.7″ W	27.7″ N	3380.437	15.04	16.2	(a)	(8, 14)
30	2000-08a	00:42:47.47	+41:15:07.5	35.5″ E	61.0″ S	1762.733	16.96[e]		(g)	
31	2000-08b	00:42:46.76	+41:12:51.8	27.5″ E	196.7″ S	1752.717	17.5[e]		(g)	
32	2005-05a	00:42:54.84	+41:16:51.5	118.5″ E	43.0″ N	3506.566	17.2	13.4	(b)	
		00:42:54.81	+41:16:51.7							
33	2005-05b	00:42:47.15	+41:15:35.7	31.9″ E	32.8″ S	3532.699	19.5		(h)	
		00:42:47.15	+41:15:35.6							
34	2005-06a	00:42:28.42	+41:16:50.7	179.3″ W	42.2″ N	3539.720	17.36	<51.6	(e)	
35	2005-06b	00:41:37.22	+41:13:11.7	756.8″ W	176.8″ S	3533.729	17.79		(e)	
36	2005-06c	00:42:31.39	+41:16:20.7	145.8″ W	12.2″ N	3544.710	16.52	6.3	(i)	
37	2005-07a	00:42:50.71	+41:20:40.2	72.0″ E	271.7″ N	3581.419	17.4	11.5	(a)	
		00:42:50.79	+41:20:39.9							
38	2005-10b	00:42:42.18	+41:18:00.1	24.2″ W	111.6″ N	3660.316	17.6	<76.2	(c)	
		00:42:42.11	+41:18:00.5							
39	2006-02a	00:42:50.68	+41:15:49.1	71.7″ E	19.4″ S	3769.248	18.0		(c)	
		00:42:50.68	+41:15:49.9							
40[f]	2004-11g	00:42:52.62	+41:18:02.4	93.5″ E	113.9″ N	3315.350	18.0			(9)
41[g]	2004-07a	00:42:43.90	+41:17:34.7	4.8″ W	86.2″ N	3181.517	18.3			(9)
		00:42:43.89	+41:17:34.9							

Notes: [a] Following CBAT nomenclature (see text); [b] discoverers of novae: (a) K. Hornoch, (b) K. Hornoch & P. Kušnirák, (c) K. Hornoch & M. Wolf, (d) K. Hornoch & L. Šarounová, (e) K. Hornoch & D. Mackey, (f) K. Hornoch, P. Garnavich, X. Zhang, T. Pimenova, (g) K. Hornoch & D. Carter, (h) K. Hornoch, P. Garnavich, B. Tucker, (i) K. Hornoch & N. Walton; [c] references for detection: (1) Hornoch et al. (2002), (2) Hornoch (2003a), (3) Hornoch et al. (2003b), (4) Hornoch et al. (2003a), (5) Hornoch & Kušnirák (2003), (6) Mobberley et al. (2004), (7) Hornoch et al. (2004), (8) Hornoch et al. (2005), (9) FBR2007. References for spectral confirmation: (10) Hornoch et al. (2002), (11) di Mille et al. (2003), (12) Hornoch et al. (2004), (13) Filippenko et al. (2004, see `http://cfa-www.harvard.edu/iau/CBAT_M31.html`), (14) Della Valle et al. (2005); [d] see Šimon et al. (2005); [e] H_{α} magnitudes; [f] discovered in the WeCAPP program (FBR2007), pre-discovery detections reported her point to an earlier date of outburst; there is significantly greater uncertainty in the position determination due to the very non-uniform background at the position of this nova; [g] discovered by Fiaschi et al. (2004, see `http://cfa-www.harvard.edu/iau/CBAT_M31.html`) and in the WeCAPP program (FBR2007).

area with smaller FOV taken with larger ground-based telescopes where WCS registration with standard catalogues normally would fail. While observations from larger telescopes normally are just used to complete Lelekovice and Ondřejov light curves to fainter magnitudes, a few novae are only detected in these images (Nos. 33 and 35) or in archival Hα images (Nos. 30 and 31).

Positions of all detected novae are given in Table B.1. We also included the pre-discovery observations of M31N 2004-11g as No. 40 and the observations of M31N 2004-07a as No. 41, that not only establish from the improved position that this nova detected by Marco Fiashi[8] end of July 2004, is the same as the nova WeCAPP N2004-04 detected on November 5, 2004, but also identifies the nova by its light curve as a slow nova. We give an internal number (Col. 1), the nova name following the CBAT nomenclature (2), the position (3, 4) and the offset in RA/Dec from the nucleus (5, 6) as well as outburst date and brightness (7, 8) and – if possible – the time interval between maximum brightness and the decay to a brightness two magnitudes below (t_{2R}) as a nova speed indicator (9). We determined these t_2 timescales with the algorithm described in Sect. 2. The derived values for novae Nos. 1−3, 5, and 8−10 nicely agree with the t_{2R} values reported by Šimon et al. (2005) using a different method. Finally, discoverers of the novae (11) and references (12) are given in which the discoveries were reported.

The photometric data (Table B.2) are separated by novae and are in semi-chronological order (the first are observations from Lelekovice in chronological order, then from Ondřejov in chronological order and finally from all other observatories in chronological order). We give the Hornoch nova number (Col. 1), nova name following CBAT nomenclature (2), time of observation as Julian date JD (3), brightness (5) and band used (7). There are also non detections for which limiting magnitudes are given indicated by ">" in the limit flag on magnitude (4), mainly closest to the time of discovery. For some novae observations before discovery are missing because no data were available (nova No. 1) or because the time between the closest none detection before the nova outburst and the nova discovery is quite long (mainly if nova was found at the begin of observational season of M 31). There are mainly *R*-band (*R*) plus some *V*-band (*V*) and narrow band H-alpha (Ha) magnitudes. Measurements with big errors are indicated by a ":" in the uncertainty flag on magnitude (Col. 6). Observers, observatory and telescope used are indicated under Cols. 8 to 10.

[8] See `http://cfa-www.harvard.edu/iau/CBAT_M31.html`