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First optical identification of a supersoft X-ray source in M31⋆

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Abstract. We propose the first association of an optical counterpart with a luminous supersoft X-ray source in M31, RX J0044.0+4118, observed with *ROSAT* in July 1991. The *PSPC* position is at 1.6″ angular distance from a candidate nova in outburst in September of 1990. This is interesting because the incidence of classical novae among supersoft X-ray sources is an open question. The proposed optical counterpart was measured at $R \simeq 17.7$ in September of 1990, and it had faded to $R > 19.2$ when it was observed again after 70 days. The light curve was too sparsely monitored for definite conclusions on the speed class of the nova. No other variable objects with $V < 23.5$ were found in the *ROSAT* spatial error box. We evaluate that the probability that a classical or recurrent nova was in outburst in the *ROSAT* error box in the few years preceding the observation is very small, so the proposed identification is meaningful. We also show evidence that the associated supersoft X-ray source turned off in the third year after the outburst.

Key words. stars: novae, cataclysmic variables – X-rays: stars

1. Introduction

Supersoft X-ray sources (SuSo) are among the most intriguing objects discovered in the past few years. Their X-ray luminosity is in the range 10^{36}–10^{38} erg s^{-1}, a non-negligible fraction of the Eddington luminosity of a 1 $M_\odot$ star (about 10^{38} erg s^{-1}). The spectrum is blackbody-like, with an effective temperature in the range 20-80 eV. The first supersoft X-ray sources were discovered with *Einstein* in the Magellanic Clouds (Long et al. 1981; Wang & Wu 1991) and later defined as a *whole new class of objects* thanks to new *ROSAT PSPC* discoveries in the Galaxy and local group galaxies (see Kahabka & van den Heuvel 1997). A wide range of sources has been classified as SuSo and they all seem to have one important feature in common: a white dwarf burning hydrogen in a shell. This class comprises the hottest PG1159 objects (e.g. Cowley et al. 1995), rare planetary nebulae with low absorption of the surrounding nebula (Wang 1991), and a large number of binary sources. Among the latter we have symbiotic stars, classical and recurrent novae, V Sge stars, and a new class of close X-ray binaries (van den Heuvel et al. 1992; Greiner 2000 and references therein).

The close binary SuSo sources are particularly interesting as candidate progenitors of type Ia supernovae. Kahabka (1999) estimates that 20% to 100% of all type Ia supernovae in M31 have SuSo progenitors. Sixteen supersoft X-ray sources (hereafter SuSo) were detected during the deep *ROSAT PSPC* pointings of M31 (Greiner 1996; Supper et al. 1997; Greiner 2000). Eighteen other *ROSAT* sources in the direction of M31 have been proposed to belong to this class (Kahabka 1999). Most fields were subsequently observed with the *ROSAT HRI* and the

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⋆ Table 3 is only available 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/389/439 positions are precise within 10–15 arcsec. It is crucial to determine the precise nature of this population and whether it is associated with M31. Yet, only nine of the sources have been scheduled for Chandra observations, which will yield arcsecond precision if the sources are not transient. Foreground sources (especially cataclysmic variables of the AM Her type, which can be as "soft" as SuSo but at least two order of magnitudes less luminous) have been excluded by Greiner et al. (1996). Some sources may be background AGN or large-amplitude outbursts of supersoft X-ray emission in active and non-active background galaxies, which have been interpreted as tidal disruption events (Komossa & Greiner 1999).

However, the number of fore- and background sources in the direction of M31 is limited, and the majority of objects in the field belong to the M31 population (at least among the original 16 SuSo identified in the deep pointings). SuSo physically belonging to M31 can be detected easily, due to the lack of strong interstellar absorption, and to the high bolometric luminosity which peaks in the supersoft X-ray range. Most other SuSo were detected in the Magellanic Clouds and not in the Galaxy (see Orio et al. 1994, 1997; Greiner 2000 and references therein). The only way to know whether one specific source belongs to M31 is to identify and study the optical counterpart.

2. Classical and recurrent novae in M31

Extrapolating from $V \simeq 11$ for the brightest SuSo in the Galaxy and $V \geq 17$ in the Magellanic Clouds, we conclude that SuSo which belong to M31 are not expected to be brighter than optical magnitude $V \simeq 22$, unless they are classical or symbiotic novae shortly after the optical outburst. Novae in M31 are known to have maximum magnitude in the range $V = 16{-}18$ (e.g. Rosino 1964a and b). The largest fraction of M31 novae peak around the low end of this range, and are mostly *slow* novae (see Capaccioli et al. 1989). As long as there is no precise Chandra position, we need to rely only on characteristics like very "blue" colour indexes, optical variability, and especially bright emission lines to identify the counterparts (see the studies of sources in the Magellanic Clouds, like Orio et al. 1997).

Classical and recurrent novae in outburst, because their brightness at maximum singles them out, are the easiest super-soft X-ray sources to identify optically in M31. However, up to now only 5 out of 120 known novae observed with *ROSAT* and other X-ray observatories in the Galaxy and Magellanic Clouds have been observed to turn into SuSo (Orio et al. 2001). Out of 120 novae observed with *ROSAT*, 44 had an outburst in the previous 10 years. Even if a fraction of Galactic novae might have been affected by huge interstellar absorption, and very few observations were repeated, the present statistics indicate only ≈10% of classical and recurrent novae turn into supersoft X-ray sources for at least few years (see Orio et al. 2001). If this is confirmed, we must conclude that, in most nova systems, the white dwarf does not retain part of the accreted mass after each outburst, a condition necessary for it to become a type Ia supernova (at least for most type Ia SNe progenitor scenarii, see Yungelson & Livio 1998). What is special and distinct about this sub-class of novae which do not expel all the accreted mass? In order to understand this issue, it is very important to broaden the statistics by studying the large number of M31 objects and identifying the novae among them.

The observed classical nova rate in M31 is 20 year^{-1}. Once it is corrected for extinction and other observational bias, the "true" nova rate turns out to be about 29 ± 4 year^{-1} (Capaccioli et al. 1989). Since the 34 SuSo candidates were observed in deep pointings that lasted for ≈2 years, we might have had about 60 novae in that time span, most of them concentrated in the bulge. However, the detection efficiency of SuSo in the bulge is reduced compared with the disk, since source crowding makes it difficult to extract the X-ray spectrum using the *ROSAT PSPC* data. This bias away from the bulge will further reduce the chance of detecting a SuSo-nova in M31. As a matter of fact, among 10 optically identified SuSo in the Magellanic Clouds, only one was a classical nova and another one a symbiotic nova. The detection rate of SuSo-novae in M31 will necessarily be lower than in the Magellanic Clouds which do not suffer the source crowding bias. Therefore, we do not expect a very large fraction of SuSo-novae in the M31 sample, but we definitely expect a few. The XMM transient XMMU J004319.4+411759 has tentatively been proposed to be a classical nova (Trudolyubov et al. 2001), even if the optical nova counterpart has not been found. Along with persistent SuSo, several transient sources exist both in the Magellanic Clouds and M31 (e.g. White et al. 1995; Orio et al. 1997) but they may not all be novae, specially considering that the Magellanic Clouds have been constantly monitored to discover nova outbursts in the last 50 years (see Orio et al. 1997 and references therein). According to Yungelson et al. (1996) and Kahabka & Ergma (1997), other transient SuSo should exist which are not classical or recurrent novae.

3. The ROSAT X-ray observations of RX J0044.0+4118

In this article we propose a classical nova as the optical counterpart of a SuSo discovered with *ROSAT*. RX J0044.0+4118 (or 2RXP J004404.8+411820) was detected in a *PSPC* exposure of M31, done in July 1991 for about 25 ksec (Supper et al. 1997). The count rate we obtain, in agreement with Supper et al. (1997), is 0.00252 ± 0.00039 cts s^{-1}. The software we used for the data analysis is EXSAS (see Zimmermann et al. 1994). The field was observed again for very short pointings with the *ROSAT PSPC* in July 1992, January 1993 and August 1993. Superimposing the images Supper (2001, private communication) obtains a 2 σ upper limit ≤0.0008 cts s^{-1}. Therefore, the flux had dropped by at least a factor of ≈4 during the third year post–outburst. In *HRI* images, including very deep exposures done in 1996, the source was not detected. The best 3σ *HRI* upper limits of 1996 are $\leq$0.0003 counts s^{-1}, corresponding to approximately $\leq$0.0026 cts s^{-1} in the *PSPC*. The rapid turn-off ($t_{\rm SuSo} \leq$ 3 years) in X-rays is not unusual for a post-outburst classical nova, as we described in Sect. 2. According to Kato (1997) 10 months $\leq t_{\rm SuSo} \leq$ 3 years translate into constraints into the nova white dwarf mass: 0.80 $M_{\odot} \leq M \leq$ 1.05 $M_{\odot}$ for low metallicity.

4. Discovery of an object in outburst in the field of RX J0044.0+4118

Members of this team (see Orio et al. 2002 for preliminary results) conduct a project using the Wisconsin-Indiana-Yale-NOAO (WIYN) 3.5 m telescope, located at Kitt Peak, Arizona, to image the fields of the SuSo in M31. We obtain magnitudes of objects in the spatial error boxes of *ROSAT*, in different colours and usually with completeness limit $\simeq$23–24 in different filters. We observed the candidate SuSo in different bands, and as first and most important step we identify the objects with U and B excess and those that are variable.

The position of RX J0044.0+4118, $\alpha_{(2000)}$ = 0h 44m 4.76s and $\delta_{(2000)}$ = +41° 18′ 20,2″ in the *ROSAT* "*rospspctotal*" catalog of *PSPC* sources in HEASARC[1], is only 1.6 arcsec distant from an object detected around 18th magnitude during observations of M31 performed in September 1990. Photometry of this field was published by Magnier et al. (1992) in the catalog of M31, obtained with CCD photometry done at the Mc-Graw Hill 1.3 m telescope of MIT at Kitt Peak, and later in an article by Nedialkov et al. (1996, see Table 1), based on plates taken at the Special Astrophysical Observatory (SAO) of the Russian Academy of Sciences 1 m telescope. By sheer chance, the dates of observation in 1990 were very close: September 17, September 19 (Magnier et al. 1992) and September 21 (Nedialkov et al. 1996). We note that the object is No. 24 in Nedialkov et al. (1996), and the position given in that paper has been revised here. Surprisingly, this object was not detected using the WIYN 3.5 m telescope in 1998 and 2000 (see Table 2). We joined efforts with different groups who have been observing M31 in the last 25 years and reviewed the observations before and after September of 1990. All the results are reported in Tables 1 and 2 (respectively, before and during, and after outburst).

The limiting magnitude is R > 20.4 in a plate obtained with the MPI Calar Alto 0.8 m telescope on 1990 August 28 (see Table 1), only 19 days before the outburst detection. The completeness limit of the photometry in September of 2000 is V > 23.5. The maximum luminosity (equivalent to $M_{\rm pg} \sim 6.5$), the range of luminosity (rise by $\Delta R \geq 2.9$ mag in about 3 weeks, decay by $\Delta V = 0.79$ mag in less than 2 days and $\Delta R > 2.5$ mag in 70 days, and $\Delta V > 5.3$ mag in a few years) suggest a classical nova in M31, which must have had an outburst on 1990, between August 30 and September 17. The V magnitude was already decreasing in the 2 days following the first detection

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Table 1. Results of observations on different nights and years: date, telescope, band of the filter, absolute magnitude or upper limit of the nova candidate and of star No. 5, the brightest star in the *ROSAT* error circle. SAO = Special Astrophysical Observatory of the Russian Academy of Sciences, BAS = Bulgarian Academy of Sciences, MGH = McGraw-Hill, MPI = Max Planck Institut (FRG). σ is the error on the magnitude or colour index of the previous column. The asterisk near "0.8 MPI" indicates that an objective prism was mounted.

date	telescope	band	mag(n)	mag(5)
1976/09/15	1.2 m MPI	B	>19.5	>19.5
1976/11/15	1.2 m MPI	B	>20.8	20.2 ± 0.1
1976/11/17	1.2 m MPI	B	>22.1	20.2 ± 0.1
1976/11/20	1.2 m MPI	B	>22.1	20.1 ± 0.1
1977/08/11	1.2 m MPI	V	>20.7	19.5 ± 0.1
1977/08/12	1.2 m MPI	B	>20.1	20.1 ± 0.1
1977/10/04	1.2 m MPI	B	>21.0	20.2 ± 0.1
1980/10/15	BAS	B	>22.0	20.0 ± 0.1
1981/10/03	BAS	B	>21.2	20.1 ± 0.2
1981/10/04	BAS	B	>21.8	20.2 ± 0.2
1981/10/05	BAS	B	>21.2	20.0 ± 0.2
1982/07/22	1.2 m MPI	B	>20.9	20.2 ± 0.1
1982/11/09	BAS	B	>22.0	20.5 ± 0.1
1982/11/13	BAS	B	>22.0	20.0 ± 0.2
1982/11/22	BAS	B	>21.5	20.2 ± 0.2
1982/11/23	BAS	B	>21.5	20.0 ± 0.2
1982/12/05	0.8 m MPI	B	>21.3	20.0 ± 0.1
1983/01/13	BAS	B	>21.5	20.1 ± 0.3
1983/08/11	BAS	B	>21.5	20.1 ± 0.2
1983/10/15	BAS	B	>21.0	20.1 ± 0.2
1983/10/16	BAS	B	>21.0	20.1 ± 0.2
1983/12/23	0.8 m MPI	R	>19.7	19.0 ± 0.2
1984/09/05	0.8 m MPI	R	>19.0	>19.0
1984/10/24	BAS	U	>21.0	20.4 ± 0.4
1985/07/18	BAS	B	>21.5	20.3 ± 0.2
1986/10/03	BAS	V	>20.5	19.1 ± 0.2
1986/11/02	BAS	V	>21.2	19.1 ± 0.1
1987/10/27	0.8 m MPI*	R	>17.5	>17.5
1990/06/29	0.8 m MPI	R	>20.5	19.0 ± 0.2
1990/07/04	0.8 m MPI	R	>20.5	19.0 ± 0.2
1990/08/02	0.8 m MPI	R	>20.4	19.0 ± 0.2
1990/08/17	0.8 m MPI	R	>19.5	18.9 ± 0.2
1990/08/28	0.8 m MPI	R	>20.4	19.0 ± 0.2
1990/09/17.44	MGH	R	17.71 ± 0.02	18.74 ± 0.01
1990/09/17.45	MGH	I	17.37 ± 0.01	18.44 ± 0.04
1990/09/17.45	MGH	V	18.05 ± 0.02	19.21 ± 0.03
1990/09/17.45	MGH	B	18.43 ± 0.04	20.00 ± 0.03
1990/09/19.35	MGH	V	18.84 ± 0.02	
1990/09/19.36	MGH	I	18.39 ± 0.02	
1990/09/20.99	0.8 m MPI	R	17.65 ± 0.08	18.83 ± 0.10
1990/09/22.03	1 m SAO	B	18.2 ± 0.1	
1990/12/12	MPI	R	≥19.20	18.73 ± 0.09

Table 2. Same as in Table 1 for observations done since the beginning of 1991. The asterisk near "0.8 m MPI" indicates that an objective prism was mounted.

date	telescope	band	mag(n)	mag(5)
1991/01/03	0.8 m MPI	R	>19.3	18.72 ± 0.07
1991/01/18	0.8 m MPI*	R	>19.8	18.8 ± 0.2
1991/06/19	0.8 m MPI	B	>20.9	20.0 ± 0.2
1991/06/21	0.8 m MPI	B	>21.1	20.2 ± 0.2
1991/08/09	0.8 m MPI	B	>19.0	18.7 ± 0.2
1991/10/01	1 m SAO	B	>20.5	20.1 ± 0.3
1991/10/06	1 m SAO	B	>22.0	20.2 ± 0.2
1991/10/07	1 m SAO	B	>22.0	20.2 ± 0.2
1991/10/09	1 m SAO	B	>21.4	20.4 ± 0.2
1991/10/12	1 m SAO	B	>22.0	20.0 ± 0.1
1991/10/29	0.8 m MPI	R	>20.5	18.8 ± 0.2
1991/11/11	0.8 m MPI	R	>120.5	18.8 ± 0.2
1991/12/12	0.8 m MPI	R	>19.3	18.9 ± 0.1
1992/01/27	1 m SAO	B	>21.5	20.3 ± 0.2
1992/01/28	1 m SAO	B	>21.0	20.0 ± 0.2
1992/02/01	0.8 m MPI	R	>19.3	18.9 ± 0.1
1992/07/28	1 m SAO	B	>21.2	20.4 ± 0.2
1992/07/29	1 m SAO	B	>21.4	20.0 ± 0.2
1992/08/03	1 m SAO	B	>21.5	20.4 ± 0.2
1992/08/05	1 m SAO	B	>21.8	20.5 ± 0.2
1992/11/23	0.8 m MPI*	R	>18.8	18.8 ± 0.1
1992/11/25	0.8 m MPI	R	>20.4	18.8 ± 0.1
1993/01/24	0.8 m MPI*	R	>18.9	18.8 ± 0.1
1994/09/27	2 m BAS	B	>21.0	20.1 ± 0.2
1994/09/27	2 m BAS	B	>21.0	20.1 ± 0.2
1994/09/28	2 m BAS	B	>21.0	20.0 ± 0.2
1994/09/28	2 m BAS	B	>21.0	19.9 ± 0.2
1996/10/10	0.8 m MPI	V	>20.5	19.2 ± 0.1
1996/12/02	0.8 m MPI	V	>19.7	19.3 ± 0.1
1997/10/30	0.8 m MPI	V	>20.0	19.4 ± 0.1
1998/08/17	WIYN	R	>20.0	18.77 ± 0.05
1998/08/17	WIYN	U	>20.2	>20.2
1999/01/19	0.8 m MPI	V	>19.7	19.3 ± 0.1
2000/08/28	0.8 m MPI	V	>21.0	19.3 ± 0.1
2000/09/26	WIYN	V	>23.5	19.18 ± 0.02
2000/09/27	WIYN	V	>23.5	19.19 ± 0.02
2000/09/27	WIYN	R	>22.0	18.77 ± 0.03
2000/10/02	6 m SAO	B	>22.5	20.08 ± 0.02
2000/10/02	6 m SAO	V	>23.0	19.20 ± 0.01
2000/10/02	6 m SAO	R	>22.5	18.74 ± 0.01
2000/10/02	6 m SAO	I	>21.5	18.27 ± 0.01

on September 17, but perhaps the object was becoming slightly redder (it could have been due to dust formation) and definitely bluer (which is indeed expected for classical novae shortly after the outburst). However, the data in Table 1 are too sparse for definite conclusions. We note that the "fragment" of light curve we have is consistent with two different types of light curves. If we caught the nova at maximum, the few points we have could fall on the light curve of a slow nova, perhaps a nova with more than one peak (see novae No. 69 and No. 80 of Rosino 1973). Such a nova would probably belong to the thick disk or bulge population (Della Valle & Livio 1998). On the other hand, if instead we missed the maximum, and the maximum magnitude was $V \simeq 16.5$, the nova could be a fast one, like nova No. 52 of Rosino (1973), and would be probably associated with the disk population. The short turn–off time in X-rays seems to point at this second possibility as more likely. The position of our nova candidate is $\alpha_{(2000)}$ = 0h 44m 04.71s $\delta_{(2000)} = 41^{\rm o}\ 18'\ 21.7''$. Six different telescopes were used and yielded the results in Tables 1 and 2, in which the magnitudes of a nearby star (No. 5) are also reported: the 1.2 m and 0.8 m of the Max Planck Institute at Calar Alto, Spain, the 1 m telescope of the SAO (Russian Academy of Sciences), the 2 m telescope of the BAS (Bulgarian Academy of Sciences), the WIYN 3.5 m telescope at Kitt Peak in 1998 August and in 2000 September, and finally the 6 m telescope of the SAO in 2000 October. The WIYN observations were done with a single CCD in August 1998 and with the Mini-Mosaic Imager (4 frames in the mosaic, obtained with 2 CCDs of 4096×2048 pixels, each read by two amplifiers) in 2000 September. An optical image obtained in 2000 September and the comparison with the plates taken during the outburst is shown in Fig. 1. The decline in luminosity of classical novae in M31 is on average slower than for Galactic novae. A decrease by more than 2.5 mag in 70 days, is only observed in about half of the M31 novae.

As it can be seen in Tables 1 and 2, we did not detect significant variability of star No. 5 and the apparent colour indexes do not suggest a very hot star (i.e. a competing "blue" candidate for the optical counterpart). Objects with larger magnitude than the completeness limit can still be detected in the different images (e.g. several stars at $V = 24{-}24.5$ in the WIYN exposures of 2000 September), but the sample is not significant below the completeness limit, which we adopt as a $\simeq 3\sigma$ upper limit. In Table 3 we give the $BVRI$ photometry for stars within the $15''$ radius error circle corresponding to the 3σ *ROSAT* position of RX J0044.0+4118, detected in at least two different bands with $V \leq 23.5$. The V magnitude, the colour indexes $V{-}R$ and $R{-}I$ and their 1σ errors. The second column reports the angular distance in arcsec from the position of the supersoft X-ray source, the last column reports the number in the catalog by Magnier et al. (1992). The nova candidate is star No. 2.

Comparing the WIYN exposures taken in two consecutive nights in 2000, in two consecutive nights in 1998, in 1990 by Magnier et al. (1992) and by Nedialkov et al. (1996), we did not find other variable objects in the spatial error box of the *PSPC* over time scales of a day or years. There are 13 other "blue" stars in Table 3 ($B - V \leq 0.4$) which we consider OB-candidates. For the stars in Table 3, detected both in the R and I passband, we plotted in Fig. 2 a colour-magnitude diagram. We also plotted the Zero Age Main Sequence and the evolutionary tracks (from Pols et al. 1998, transformed in I versus $R - I$ using the Basel interactive server, see Lejeune et al. 1997), for $M = 2$ and 4 $M_{\odot}$, adopting the average foreground extinction towards M31 $E(B - V) = 0.062$ (see Schlegel et al. 1998). In Fig. 3 we plotted instead a colour-colour

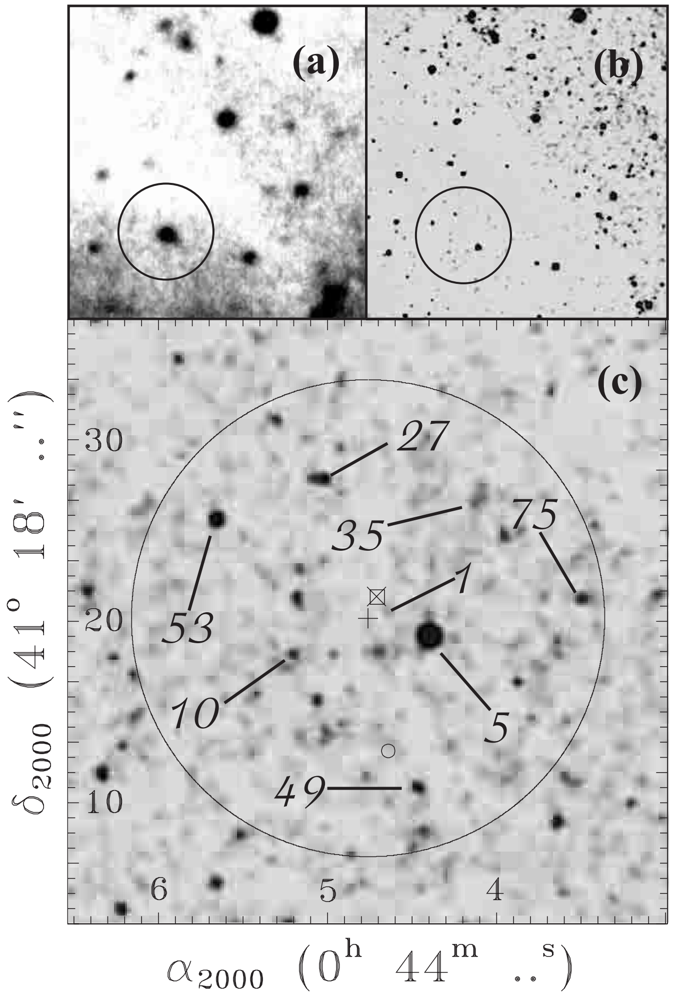

Fig. 1. A 15″ error circle around the *ROSAT* position of the supersoft X-ray source RX J0044.0+4118 is plotted here on different images. The small image on the left **a)** was obtained in B band by Nedialkov et al. (1996) on September 21 1990 and image **c)** which is a part of **b)** was obtained in the V band with the WIYN 3.5 m telescope in 2000 September. The position of the putative nova is indicated by the open square (as measured by Nedialkov et al. 1996) and by the "X" (as measured by Magnier et al. 1992) and in Table 3 we report the photometric measurements obtained for all the stars in the error circle. We show in **c)** the brightest stars of Table 3.

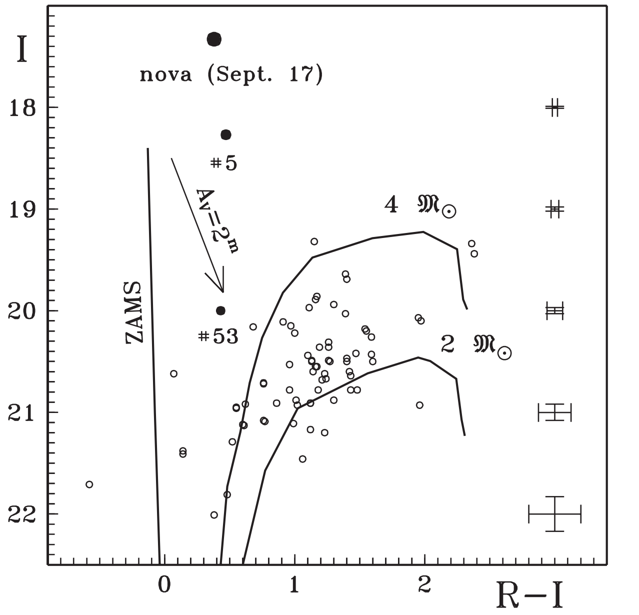

Fig. 2. Color-magnitude diagram for 77 stars with RI photometry in Table 3. The approximate location of ZAMS at the distance modulus $(m-M)_0 = 24.47$ of M31 (Stanek & Garnavich 1998) is shown. The evolutionary tracks for $M = 2$ and 4 $M_\odot$ are also plotted (see text). The arrow indicates the reddening vector corresponding to the classical extinction law of Mathis (1990), and $R_V = 3.1$. The filled circles represent the magnitudes and colours of the candidate nova on Sept. 17 1990, and of the two brightest stars (No. 5 and 53) within the 15″ error circle from the nova. On the right the average errors for different values of V are shown.

diagram for the stars with B, V and I detections. In both figures we show the position of star No. 2, our candidate nova, when it was observed in September of 1990. Because most stars detected in the three colours B, V and I are very faint, the points are spread in Fig. 3, with large errorbars. Fourteen stars in the figure deviate from the expected range of the extinction law. However, this could be due to blending with neighbouring stellar images (low mass OB star on the main sequence and AGB star).

It can be clearly seen that the nova candidate stands out in the upper left corner in the colour-magnitude plot (Fig. 2) and that it had typical colours of a not heavily absorbed nova (Fig. 3; note that we consider $E(B-V) = 0.16$ intrinsic to M31). The variability time scales we sampled for the putative nova are several years by comparisons with different telescopes; with WIYN alone we sampled ≃2 years between 1998 and 2000, 1 day, and few minutes over a 2 hour period. The only detection and the only outburst we discovered are the ones of 1990 September 17–21.

Finally, we would like to add a few remarks about the stellar population within the 15″ error circle. Figure 2 shows that it is dominated by an old disk population (71 of total 86) of AGB stars, clumped around the values $(R-I) = 1.2$ and $I = 20.5$ and belonging to the "Tip of the AGB" (see HST photometry by Sarajedini & Duyne 2001). The interval between the evolutionary tracks (Pols et al. 1998) for 2 and 4 solar masses and $0.9 < (R-I) < 1.6$ corresponds to stellar ages in the range of 0.2–1.5 Gyr. Most of the other 15 stars (excluding the nova) could be OB stars according to different colour criteria (such as $(B-V) < 0.4$, for example). The *ROSAT* error circle is located out of the boundaries of OB associations in M31 and there are no indications of recent star formation. Moreover, we also obtained an Hα image with the WIYN telescope in 2000 September, and failed to detect any diffuse nebulosity, which seems to exclude the presence of an HII region other than No. 23 of

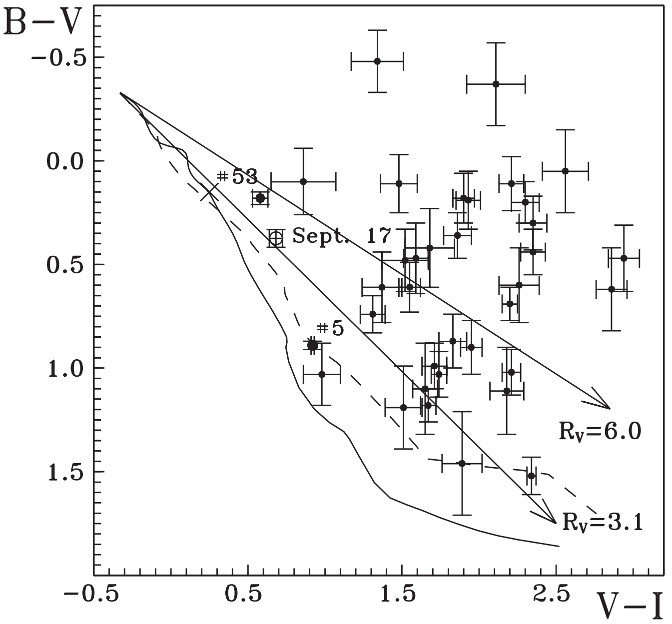

Fig. 3. Two-colour diagram for the 37 stars from Table 3 with BVI photometry. The solid line is the location of supergiant stars and the long dashed line is the location of main sequence stars (Bessell 1990). The two arrows represent the reddening vector typical for the "diffuse" ($R_V = 3.1$) and the "dense" ($R_V = 6.0$) interstellar medium (Mathis 1990). The open circle indicates the position of the candidate nova in this diagram on Sept. 17, 1990 and the two filled circles indicate the positions of stars No. 5 and 53 in September of 2000. The mean locus for Galactic novae at maximum, $(B-V)_o = 0.15$ (Cohen 1985), is marked with an "X".

Table 3, k282. Star No. 5, the brightest one in the field ($V = 19.2$), could be a reddened OB supergiant although neither apparent colour indexes nor dereddening according to the classical extinction law ($R_V = 3.1$) suggest a very hot star. Examining a 25 times larger area centered at the X-ray source position and comparing it with the possible foreground contamination (negligible for a circle with a radius of 15″) leads to only a 10% probability that star No. 5 belongs to the Galaxy. It is more likely to be an OB star in M31. Star No. 53 it is the brightest M31 main sequence OB candidate, at $V = 20.6$. Its absolute magnitude could be as large as $M_V = -5.8$ after dereddening with $A_V = 2$ mag. Some of the other blue star candidates are too faint to be detected in shorter wavelengths and they are not shown in Fig. 2.

5. The probability of a random coincidence

Although probably only 10% of all classical and recurrent novae turn into SuSos (see Orio et al. 2001), and our colour index and variability study with the WIYN can detect only up to ≈50% of all possible SuSo counterparts (we estimate the rest to be at $V \leq 24.5$) we are able to show that the possibility of a random spatial coincidence between the proposed nova and RX J0044.0+4118 is *not* high. About 85% of the novae discovered in M31 are located within 12 arcmin from the center of M31. Their number decreases with distance from the center. RX J0044.0+4118 is at a distance 15.29 arcmin from the center of M31, which we consider to be $\alpha_{(2000)} = 0$h 42m 44.16s and $\delta_{(2000)} = 41^{\circ}\ 16'\ 08.6''$. From the data published by Capaccioli et al. (1989), we estimate that the probability that one of the novae in outburst and observed in one year falls in a 15 arcsec spatial error box at a distance 15.29 arcmin from the center of M31 is only $\approx 1.5 \times 10^{-4}$, or in other words in 10^5 years we expect only 15 novae in the error box. Even smaller is the probability of random coincidence with a recurrent nova. Della Valle & Livio (1996) have shown that the ratio between the rate of outbursts of recurrent and classical novae is in the range 0.1–0.3, thus the probability to run into a non-physical coincidence is not larger than 0.05% Assuming that the constant bolometric luminosity phase lasts for the upper limit we have on the life of RX J0044.0+4118 as SuSo, 3 years, we obtain a 0.05% probability to detect a nova within a 15 arcsec spatial error box of a SuSo, without being physically associated with it. We point out that this is even a very conservative conclusion, assuming that *all* the sources discovered in the M31 direction belong to the galaxy and *all* novae turn into SuSo. However, since observational estimates suggest that only about 10% of novae are detectable for few years in supersoft X-rays, it is likely that the probability of a random coincidence is even smaller than quoted above, probably of the order of ∼0.01%.

6. Conclusions

The nature of the population of SuSo in M31 is still to determine, and in this article we "broke the ice" by proposing the identification of one of the sources, RX J0044.0+4118, with a candidate classical nova, which must have been in outburst 10 months before the *ROSAT* observations. Since the statistics on Galactic novae are still very incomplete, it is important to determine how frequently extragalactic novae turn into SuSo and how they contribute to the SuSo population in near-by galaxies. Moreover, this object would be only the sixth classical nova ever observed to become a SuSo (four were observed in the Galaxy and one in the LMC). Turn-off in supersoft X-rays occurred after about two years, which makes this object similar to the Galactic nova V1974 Cyg (Krautter et al. 1996).

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