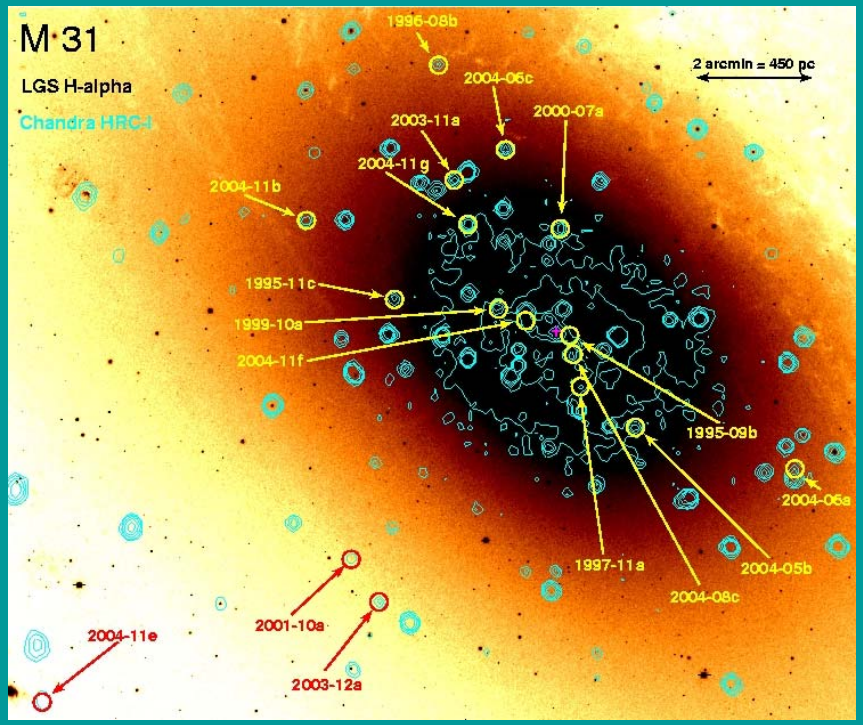
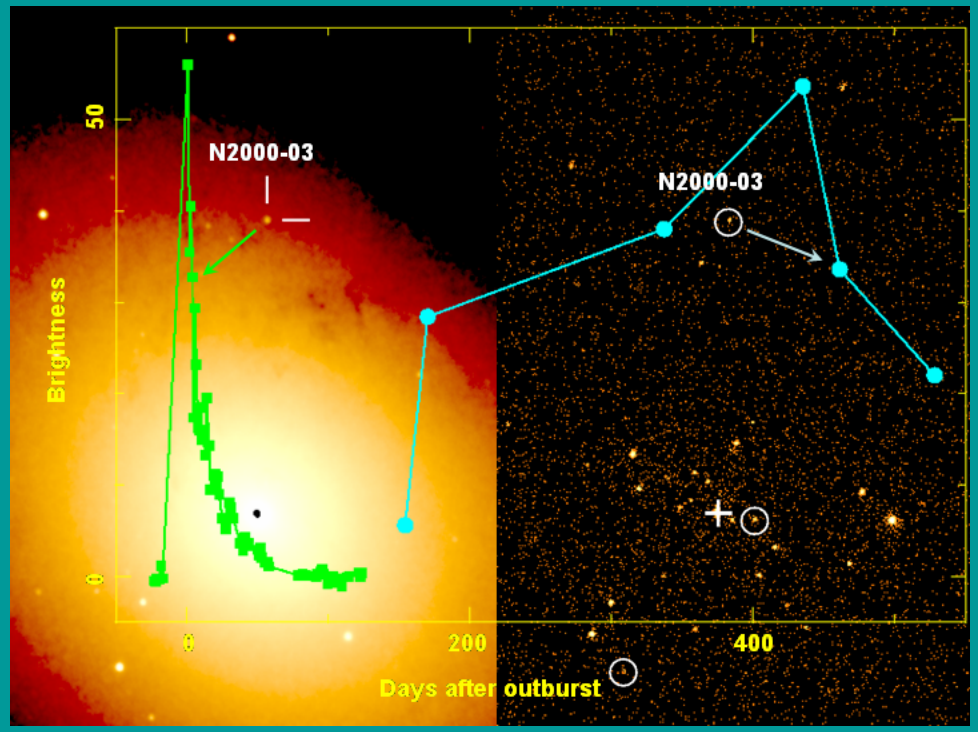
X-ray emission from optical novae in M 31





Wolfgang Pietsch (MPE)

Outline

- Introduction to SSS emission from novae in M 31
- First XMM-Newton survey of M 31
- Optical novae: the major class of SSS in M31
- The M 31 nova web page
- Chandra HRC nova detections 2004/5
- Ongoing nova search program in M 31 with optical telescopes and spectral characterization
- Position improvement and search for novae on archival plates
- Ongoing XMM-Newton/Chandra monitoring of the center field of M 31, Swift follow-up
- Periodicities in M31N 2007-12b
- Statistics and outlook

ROSAT AO1 proposal 1989 (I)

DEEP SURVEY OF THE ANDROMEDA NEBULA

Principal Investigator : J.Trümper

Co-Investigators : W. Pietsch, G. Hasinger, R. Hessmann, J. v. Paradijs, W.H.G. Lewin, H.C. Arp, B. Aschenbach, H.H. Fink, M. Gottwald

Scientific Justification:

Novae have been identified as a new class of luminous X-ray emitters in our Galaxy in the soft energy band (above 10^{37} erg s^{-1} , see Ögelman et al. 1987). They stay at high luminosity for several years after outburst. Due to the relatively low galactic N_H ($7 \times 10^{20} cm^{-2}$) in the direction of M31 it will be possible to detect novae if they are not obscured by too high an N_H within M31 (figure 4 gives limits for a 5 σ and 3 σ detection, see feasibility). Nova searches in M31 give a nova rate of about 30 per year (Arp 1956). 90% of the novae seem to occur in the bulge while the rest are found in the disk (Ciardullo et al. 1987). If novae stay visible in X-rays for 5 to 10 years at about the same luminosity as indicated by the *EXOSAT* observations one could see several tens of the X-ray brighter novae in M31. To assure the identification of soft sources found with novae, we have initiated a nova search program at Heidelberg.

I declare that this proposal has been submitted only to:

BMFT <delete TWO agencies>

Signature: [signature] Date: 5.5.89

ROSAT AO1 proposal 1989 (II)

Feasibility:

Since novae might constitute a completely new class of X-ray sources detectable in nearby galaxies we investigated seperately the feasibility for this type of objects. In fig. 4 we show the temperature/luminosity range allowed for 3 novae observed with *EXOSAT* (Õgelman et al. 1987). For the corners of the parameter range marked by a, b, c, d and the center (e) table 3 gives the number of *ROSAT* PSPC counts assuming the source to be located in M31 (distance 720 kpc, intervening N_H of $7 \times 10^{20} cm^{-2}$, soft energy band 0.02 - 0.5 keV, 50" detect cell).

Fig. 4

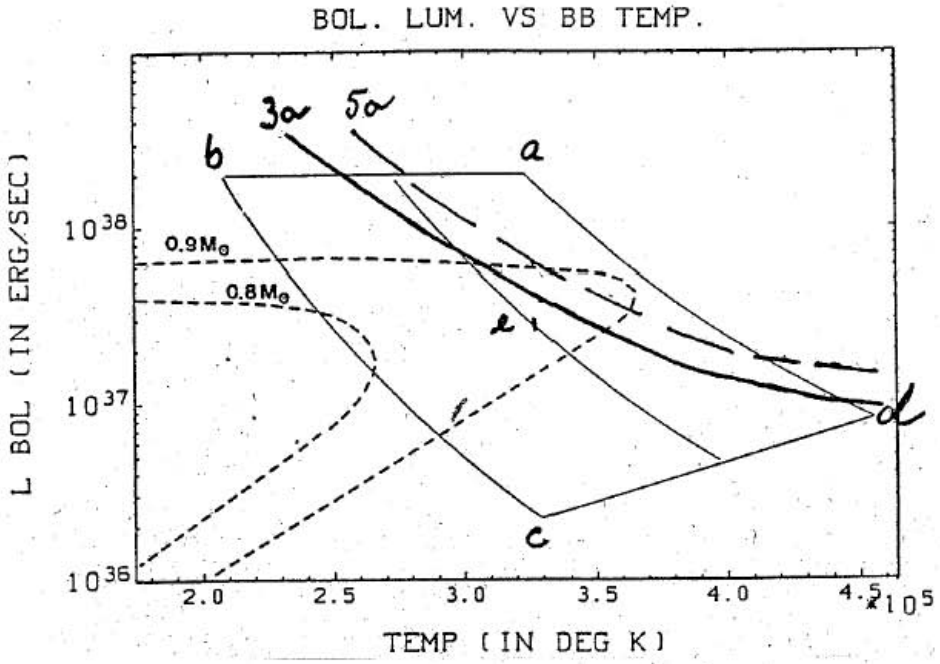


Table 3

	30 ksec	60 ksec
a	102	204
b	4	8
c	0	0
d	15	30
e	11	22

The expected PSPC background is 75 cts and 150 cts in the detect cell in the soft energy band, respectively. Novae showing more than 43 cts or 61 cts would be detected at the 5 σ level. Coincidences with nova positions as determined in our optical nova search would already be significant for 3 σ X-ray detections. Novae, to be detected in a 60 ksec M31 observation, have to be in the parameter space above the 3σ or 5σ line in Fig. 4.

A&A 389, 439–445 (2002)
DOI: 10.1051/0004-6361:20020575

Astronomy & Astrophysics

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

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[10] University of Hawaii, Institute for Astronomy, 2680 Woodlawn Dr., Honolulu, HI 96822, USA
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Received 19 December 2001 / Accepted 11 April 2002

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.

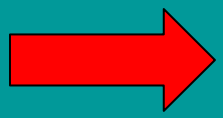
Key words. stars: novae, cataclysmic variables – X-rays: stars

Optical Nova detected at SSS position

[SHP97] 268 = M31N 1990-09a

Why M31 optical nova/SSS observations?

- Optical
  - Detection
  - Light curves
  - Spectral classification
- X-ray
  - Light curves (start and end of SSS phase)
  - Spectra (temperature, absorption, luminosity)
- Results
  - Mass of ejected matter
  - Burned mass
  - White dwarf masses



Some recurrent novae precursor of type Ia Supernovae?

Modeling of nova SSS state

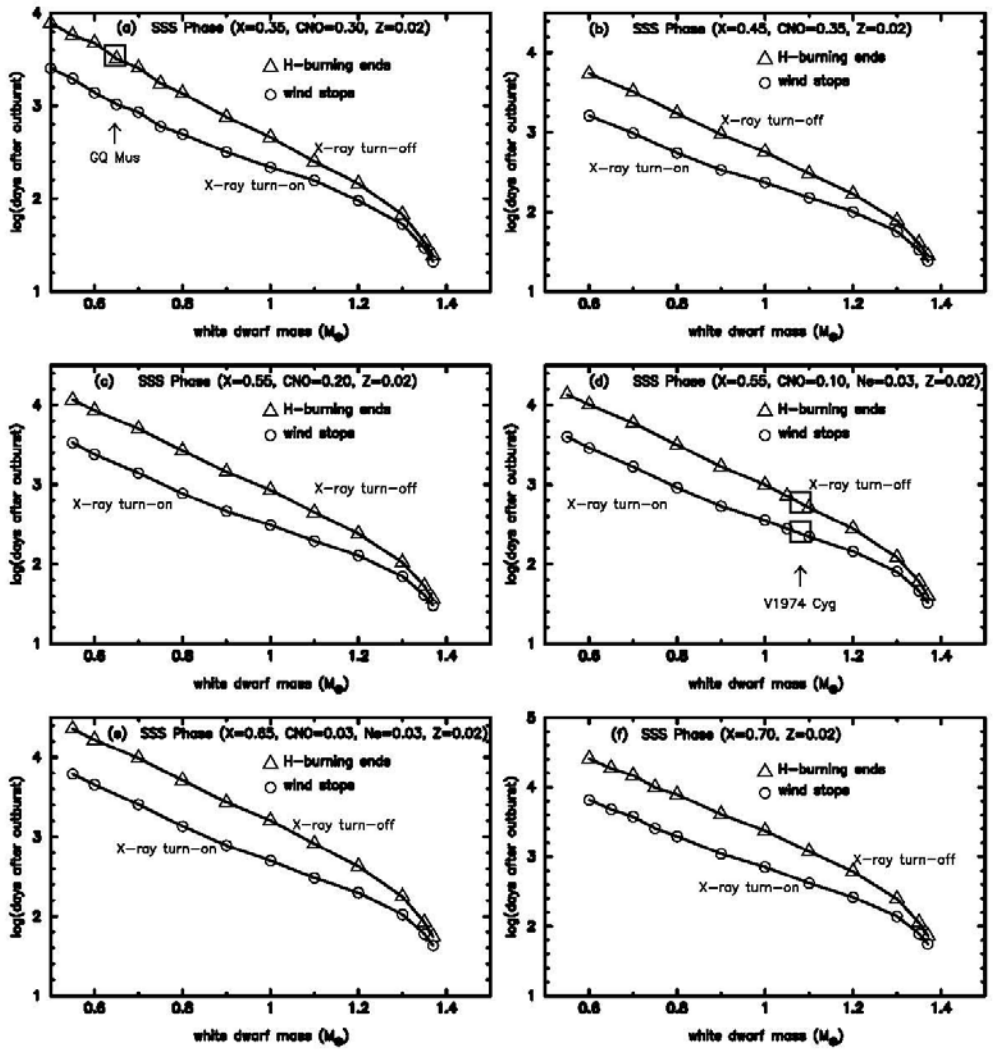


FIG. 3.—Turn-on (*circles*) and turnoff (*triangles*) times of supersoft X-ray are plotted against the WD mass. X-ray turn-on corresponds to the epoch when optically thick winds stop, while X-ray turnoff corresponds to the epoch when hydrogen shell-burning ends. A total of 72 cases are plotted for six different chemical compositions: (*a*) case CO 2 in Table 2, a large square indicates the epoch of supersoft X-ray turnoff for GQ Mus 1983 (Shanley et al. 1995); (*b*) case CO 3; (*c*) case CO 4; (*d*) case Ne 2, two large squares indicate the epochs of supersoft X-ray turn-on and turnoff for V1974 Cyg 1992 (Krautter et al. 1996); (*e*) case Ne 3; (*f*) solar composition. [*See the electronic edition of the Supplement for a color version of this figure.*]

Ejected mass
Burned mass
WD mass
Chem. Comp.

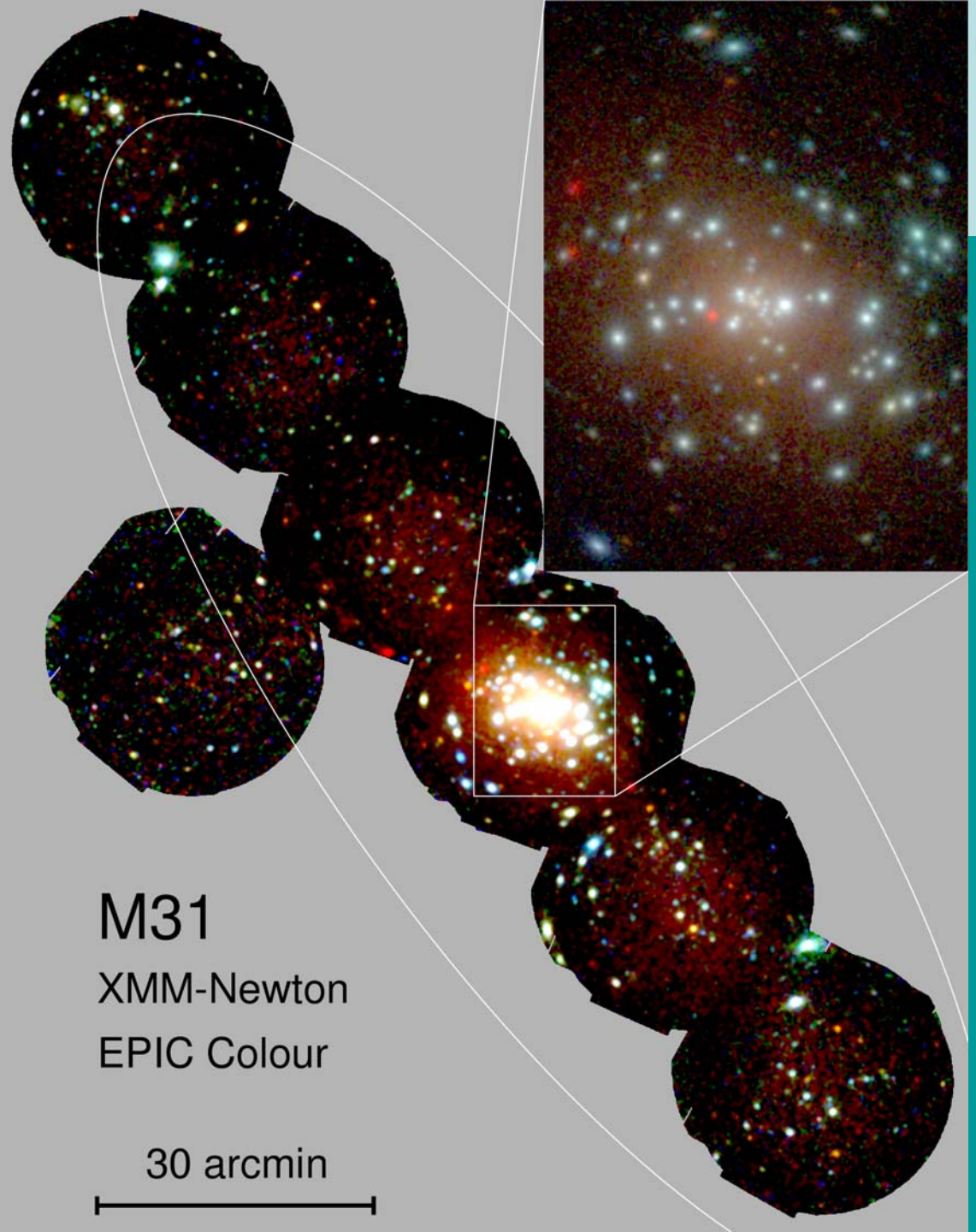
e.g.

Sala & Hernanz 2005
A&A 439, 1061

Hachisu & Kato 2006
ApJS 167, 59

Observations of optical novae in M31

- 30 to 50 novae per year in M31
- More than half of the novae in bulge area
- Several candidates for recurrent novae
- Monitoring of bulge area gives light curves of many novae simultaneously in one XMM-Newton/Chandra field (Galactic novae can only be monitored one by one, i.e. observation time used much less efficient)
- Only X-ray observations with good low energy sensitivity can detect SSS efficiently (EPIC pn, HRC-I, ACIS-S)
- Archival X-ray observations have un-regular sampling
- Dedicated XMM-Newton/Chandra proposals accepted
  - AO5: eight observations with 1.5 month separation distributed over one year
  - AO6, AO7, AO8: 3x ten observations with 10 day separation distributed over about 3 months, each
- Detection of optical novae in the optical and spectral classification essential for interpretation of X-ray data



The Andromeda Galaxy M 31

W. Pietsch, M. Freyberg, F. Haberl et.al. 2004, A&A 434, 483

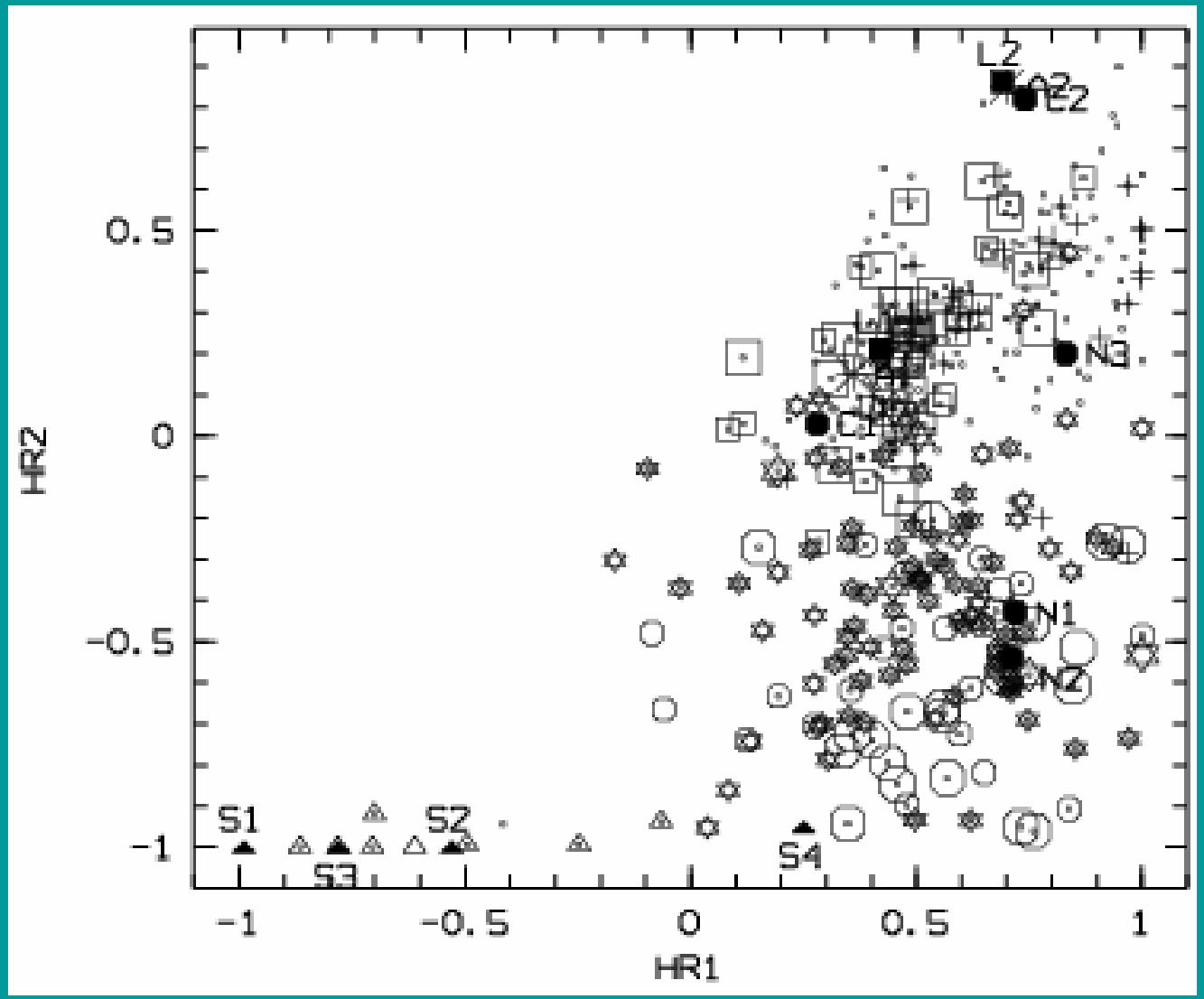
- Similar analysis to M 33 based on archival data
- 856 sources in fields
- Hardness ratio and time variability
- classification and identification

➡ XMM-Newton large program (Holger Stiele)

Hardness ratio plots of M 31 sources

$HRi = (Bi+1 - Bi)/ (Bi+1 + Bi)$

B1: 0.2-0.5 keV
B2: 0.5-1.0 keV
B3: 1.0-2.0 keV
B4: 2.0-4.5 keV
B5: 4.5- 12 keV

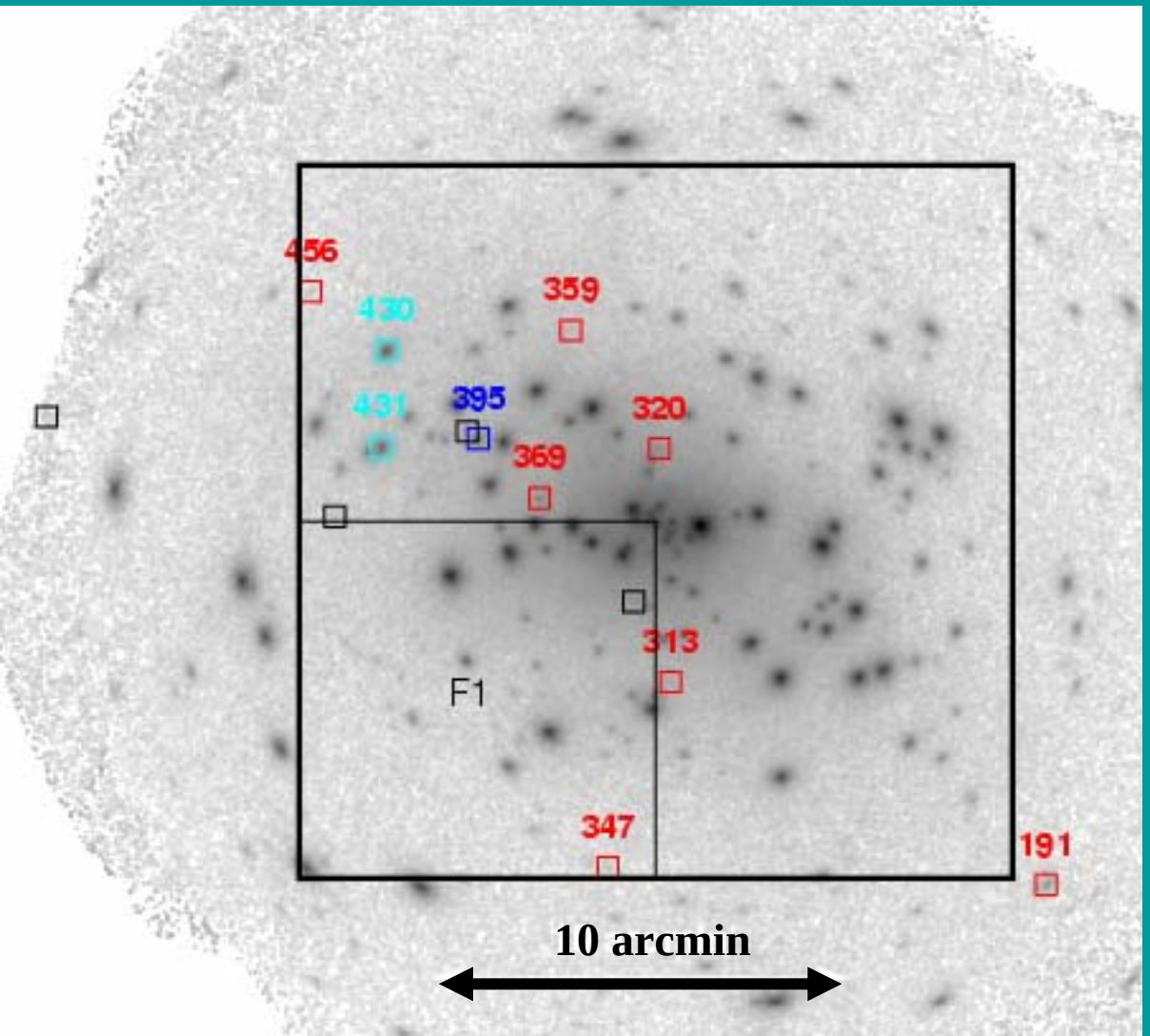


fg-star
AGN
SSS
SNR
XRB

Optical novae: the major class of supersoft X-ray sources in M 31

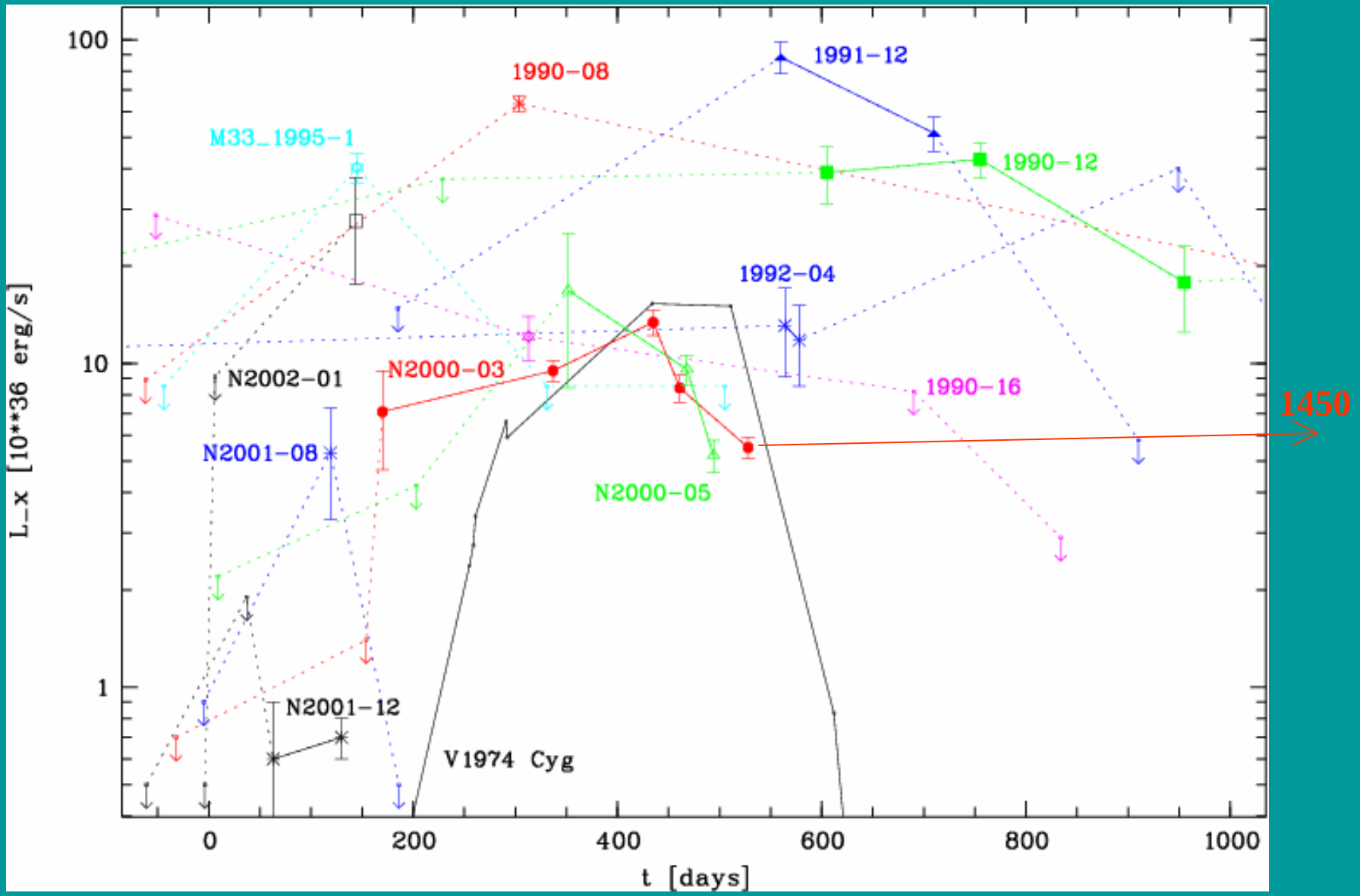
Pietsch, Fliri, Freyberg, Greiner, Haberl, Riffeser, Sala 2005, A&A 442, 879

2006, A&A 454, 773



- search for optical nova correlations in XMM-Newton, Chandra and ROSAT catalogs and archival observations
- 21 X-ray counterparts in M 31 and 2 in M 33
- novae dominant class of supersoft X-ray sources in M 31 center

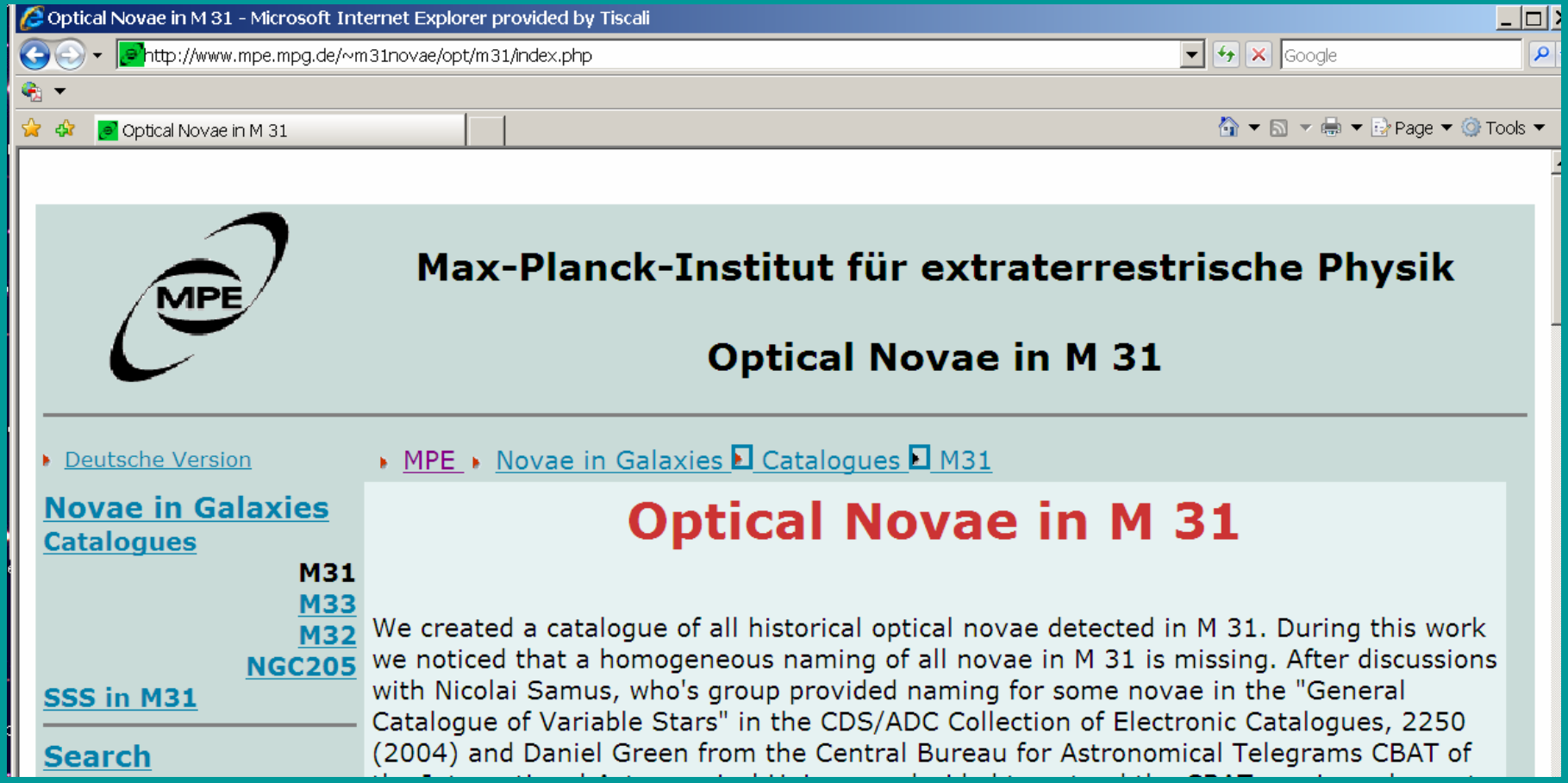
X-ray nova light curves (<1000 d)



Summary optical novae

- Novae established as major class of SSS in M 31 center
- Spectra can be modeled by BB spectra (T <80 eV)
- Novae as SSS best detectable with XMM-Newton EPIC pn, Chandra HRC I and ACIS S
- SSS state of novae may be shorter than half a year, several novae missed in optical and X-ray searches
- Start time of SSS state gives estimate of ejected hydrogen mass for two novae (~10^{-5} M_o and ~10^{-6} M_o)
- SSS state of at least 15% of novae turned on within a year
- At least one of the novae showed SSS state lasting to 6.1 years after optical outburst (similar to GQ Mus and Nova LMC 1995)
- Six of the SSS turned on between 3 and 9 years after optical outburst and may be recurrent novae. This could indicate larger SSS rate among recurrent novae than among classical novae or that percentage of recurrent novae in M 31 has been strongly underestimated
- M31 optical nova catalog with homogeneous naming on http://www.mpe.mpg.de/~m31novae/opt/m31/M31_table.html

M31 optical nova catalog I

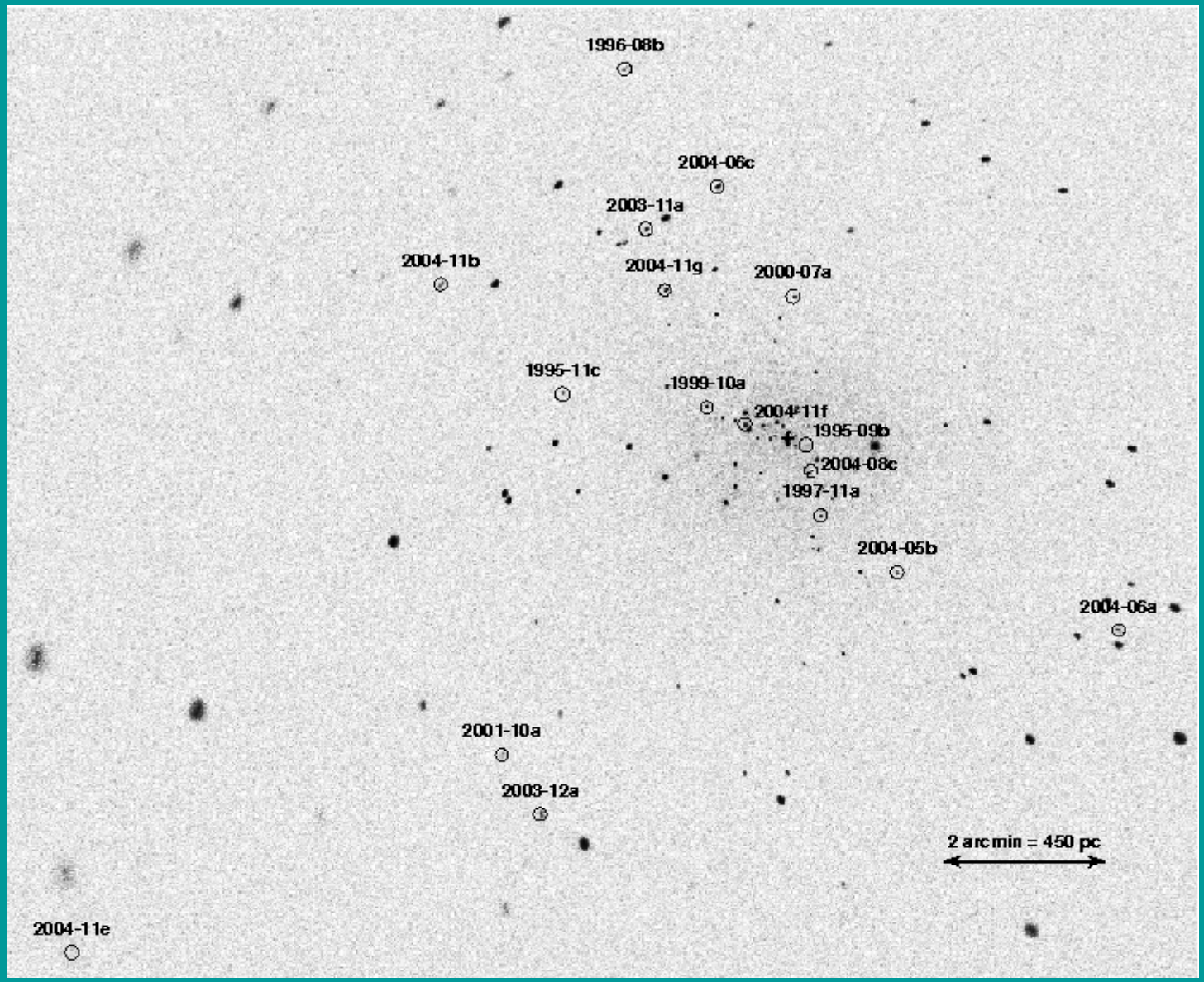


M31 optical nova catalog II

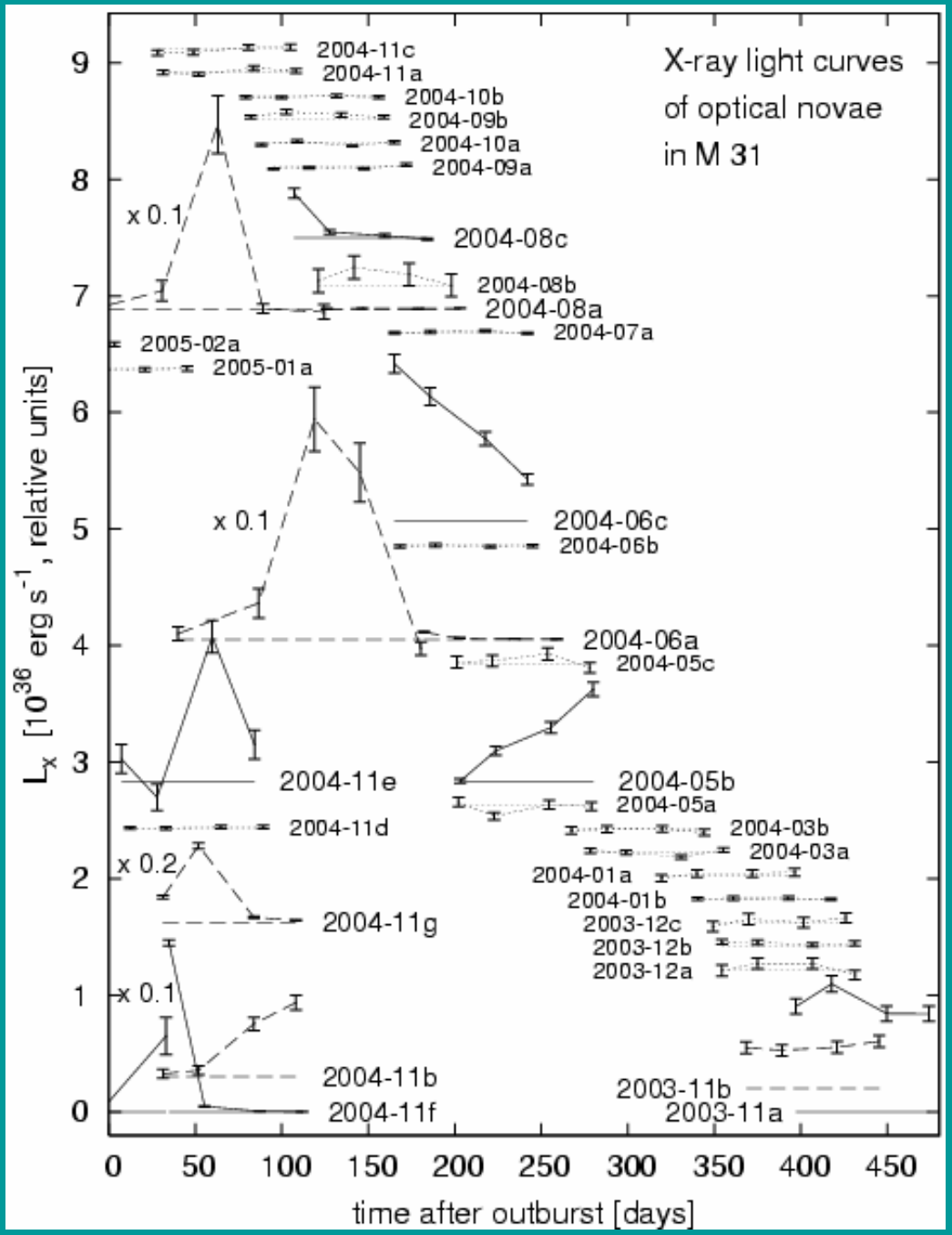
name M31N	RA DEC	error	Pos_ref	JD	JD_ref	ID_out	ID_ref	MAG	Filt	M_ref	T2_1	T2_2	T2_ref	alt. name
2009-02b	00 : 42 : 27.77 + 41 : 13 : 42.4	0.3 0.3	364	2454882.63	364			18.5	R	364				
2009-02a	00 : 43 : 43.81 + 41 : 36 : 38.8	1.0 1.0	360	2454868.93	360	a	360	16.8	w	360				
2009-01a	00 : 44 : 44.03 + 41 : 23 : 28.3	0.5 0.5	356	2454859.92	356			18.5	w	356				
2008-12b	00 : 43 : 04.85 + 41 : 17 : 51.6	0.3 0.3	353	2454830.21	354	a	353	16.8	w	353				P60-M31-081230
2008-12a	00 : 45 : 28.80 + 41 : 54 : 10.1	0.5 0.5	352	2454826.98	352			18.7	w	352				
2008-11c	00 : 43 : 18.62 + 42 : 10 : 14.2	0.5 0.1	342	2454797.00	342			18.2	w	342				

alt. names	alt. ref.	spectral ref.	x-ray ref.	finding charts	spectra	com
	365 , 366 , , ,	, ,	, ,	SuperLOTIS , LGS		rec. cand. 99.44y M31N1909-09b (367)
	361 , , , ,	362 , ,	, ,	Nishiyama , LGS		FeII (362)
	, , , ,	359 , ,	, ,	Nishiyama , LGS		FeII, slow nova? (359)
)	355 , , , ,	354 , ,	, ,	Nishiyama , LGS		FeII (354)
	, , , ,	, ,	, ,	Nishiyama , LGS		
	345 , , , ,	343 , 344 ,	, ,	Itagaki , DSS2		not a nova, SN z=0.07 (343, 344)

Chandra detections of optical novae in M31 from Jul 2004 to Feb 2005



Pietsch, Haberl, Sala, Stiele, Hornoch, Riffeser, Fliri, Bender, Bühler, Burwitz, Greiner, Seitz 2007, A&A 465, 375


X-ray light curves
of optical novae
in M 31
2004-11c
2004-11a
2004-10b
2004-09b
2004-10a
2004-09a
x 0.1
2004-08c
2004-08b
2004-08a
2004-07a
2005-02a
2005-01a
x 0.1
2004-06c
2004-06b
2004-06a
2004-05c
2004-11e
2004-05b
2004-05a
2004-11d
2004-03b
2004-03a
x 0.2
2004-01a
2004-01b
2004-11g
2003-12c
2003-12b
2003-12a
x 0.1
2004-11b
2003-11b
2004-11f
2003-11a
L_X [10^{36} erg s^{-1}, relative units]
time after outburst [days]
0
50
100
150
200
250
300
350
400
450
1
2
3
4
5
6
7
8
9

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.

Main results from 2007 paper

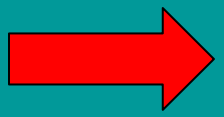
- 11 out of 34 novae detected within a year
- For 11 novae (mainly from paper I) end of SSS phase is detected
- 7 novae still bright 1200,1600,1950, 2650, 3100, 3370 and 3380 days after outburst
- One turns on after 50 d, one 200 d after outburst
- 3 novae short X-ray outbursts starting within 50 d after optical outburst and lasting only 2-3 months
- X-ray emission SSS from spectra or count rate comparison of Chandra HRC I and ACIS I
- Number of detected novae much higher than previously estimated (>30%)
- X-ray light curves give estimates for masses and burned masses of White Dwarfs and of ejecta

Analysis of archival plates

- Important for secure identification of recurrent novae
- Digitized Tautenburg Schmidt plates of M 31
  Henze, Meusinger, Pietsch 2008, A&A 477, 67
  - 55 nova candidates (22 new)
  - Improved positions for 84
- Digitized “Rosino” plates
  (collaboration with M. Orio, improved positions in work)
- Other novae on archival plates should also be digitized and re-analysed
  - Sharov and Alksnis plates (info on request)
  - Hubble, Bade, Arp plates?

M 31 XMM large program

- Covered full disk of M 31 in observations from June 2006 to February 2008
- Some fields covered more than once due to high background
- No monitoring, just snapshots
- Still some novae detected



Talk by Holger Stiele

M31 optical nova monitoring consortium

X-ray:

- W. Pietsch, R. Bender, V. Burwitz, M. Freyberg, J. Greiner, F. Haberl, M. Henze, A. Rau, H.Stiele, MPE Garching
- J. Fliri, A. Riffeser, S. Seitz, Uni Sternwarte Muenchen
- D. Hatzidimitriou, P. Reig, University of Crete
- M. Hernanz, IEEC Spain
- D. Hartmann, Clemson University
- M. Orio, University of Wisconsin, INAF Osservatorio di Torino
- G. Sala, IEEC-UPC Spain
- M. Della Valle, Osservatorio Astrofisico di Arcetri, Firenze

Optical monitoring:

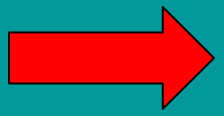
- Skinakas 1.3m, 60cm
- Super-LOTIS 60cm
- La Sagra 45cm
- Collaboration with amateurs (K. Hornoch; K. Nishiyama & F. Kabashima)

Optical spectroscopy:

- Skinakas 1.3m
- SAO 6m
- Palomar 200inch
- Fast information of interested observers (F. Di Mille, A. Shafter)

First results from AO5, AO6 and AO7 M 31 optical nova monitoring

- Optical novae and SSS in M 31 globular clusters
  Henze et al. 2009, A&A in press
- Fast supersoft X-ray emission from M31N 2007-11a
  Henze et al. 2009, A&A 498, L13
- Short term time variability in SSS light curve of M31N 2006-04a
- Some first statistics



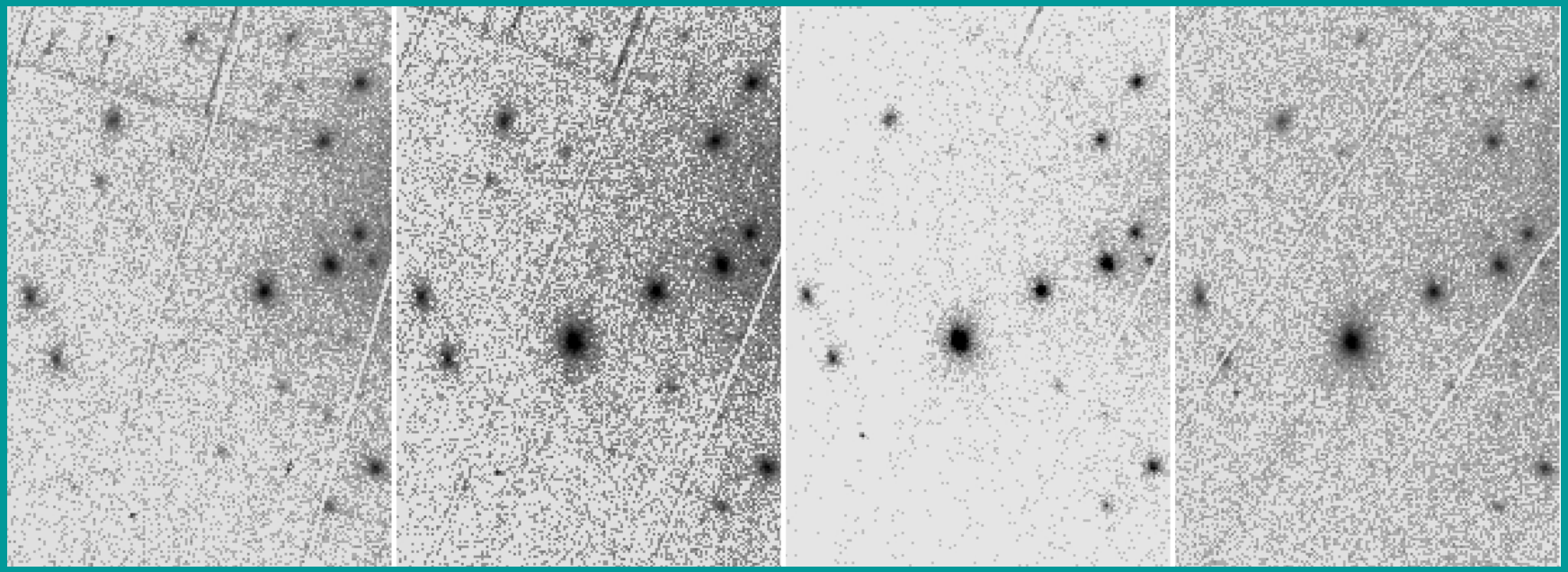
See talk by Martin Henze

- 1105 s pulsations in the supersoft emission from the He/N nova M31N 2007-12b
  Pietsch et al. in preparation

He/N nova M31N 2007-12b

- Optical detection 2007 Dec 9.5 (16.1 w) Nishiyama & Kabashima
  at Miyaki-cho
  at Wendelstein Lee et al. ATel 1324
  and Kamil Hornoch
- Optical Spectrum at HET: Hα 4500 km/s FWHM, He/N type Shafter ATel 1332
- X-ray XMM-Newton 2007 Dec 29 ?faint
  2008 Jan 8 bright, puls.
  Swift Jan 13 bright
  Kong & Di Stefano ATel 1360
  XMM-Newton 2008 Jan 18 bright, puls.
  Jan 28 bright, puls.
  Feb 7 bright, puls.
- Start of SSS within 30 days, duration?

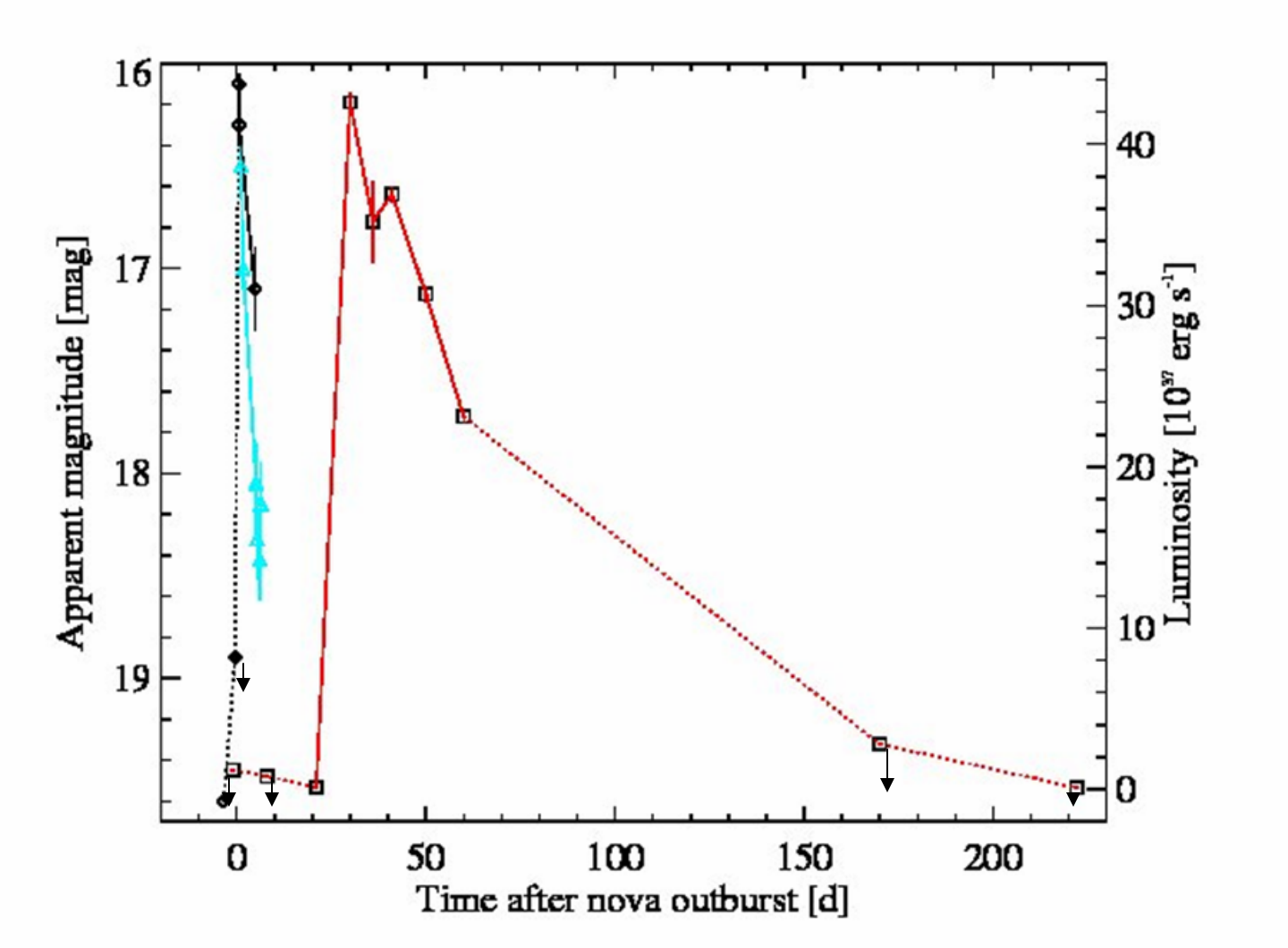
M31N 2007-12b EPIC pn images



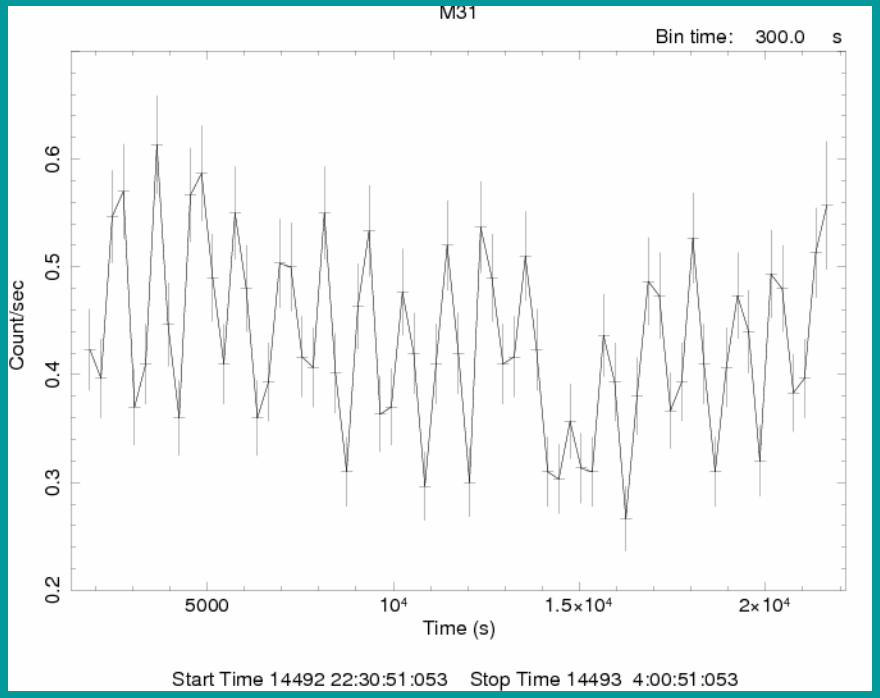
2007 Dec 29 2008 Jan 8 2008 Jan 18 2008 Jan 28

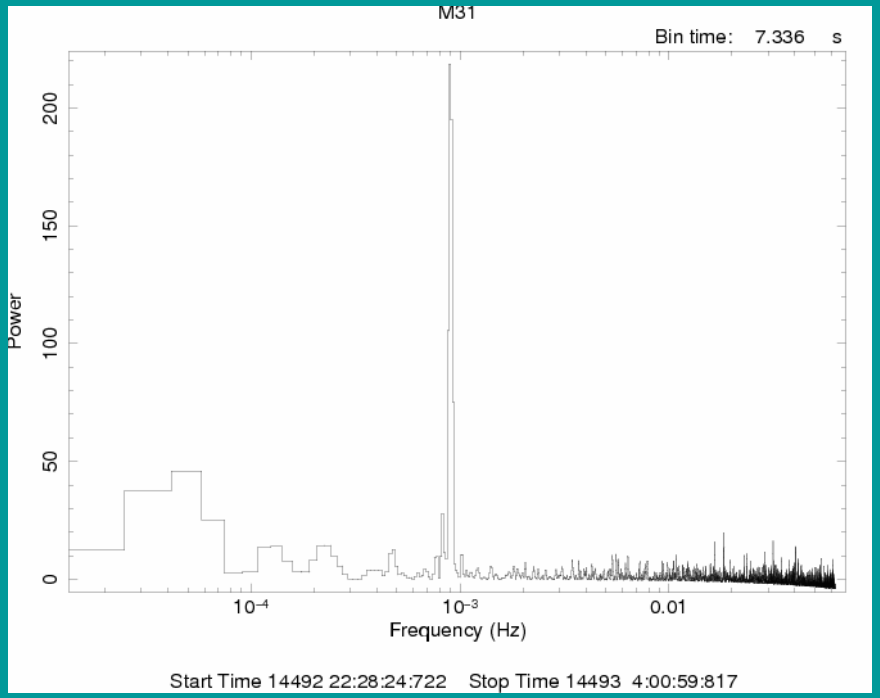
XMM-Newton EPIC pn 200-1000 eV

M31N 2007-12b light curve



Pulsations in X-ray emission from M31N 2007-12b (e.g. 2008 Jan 28)



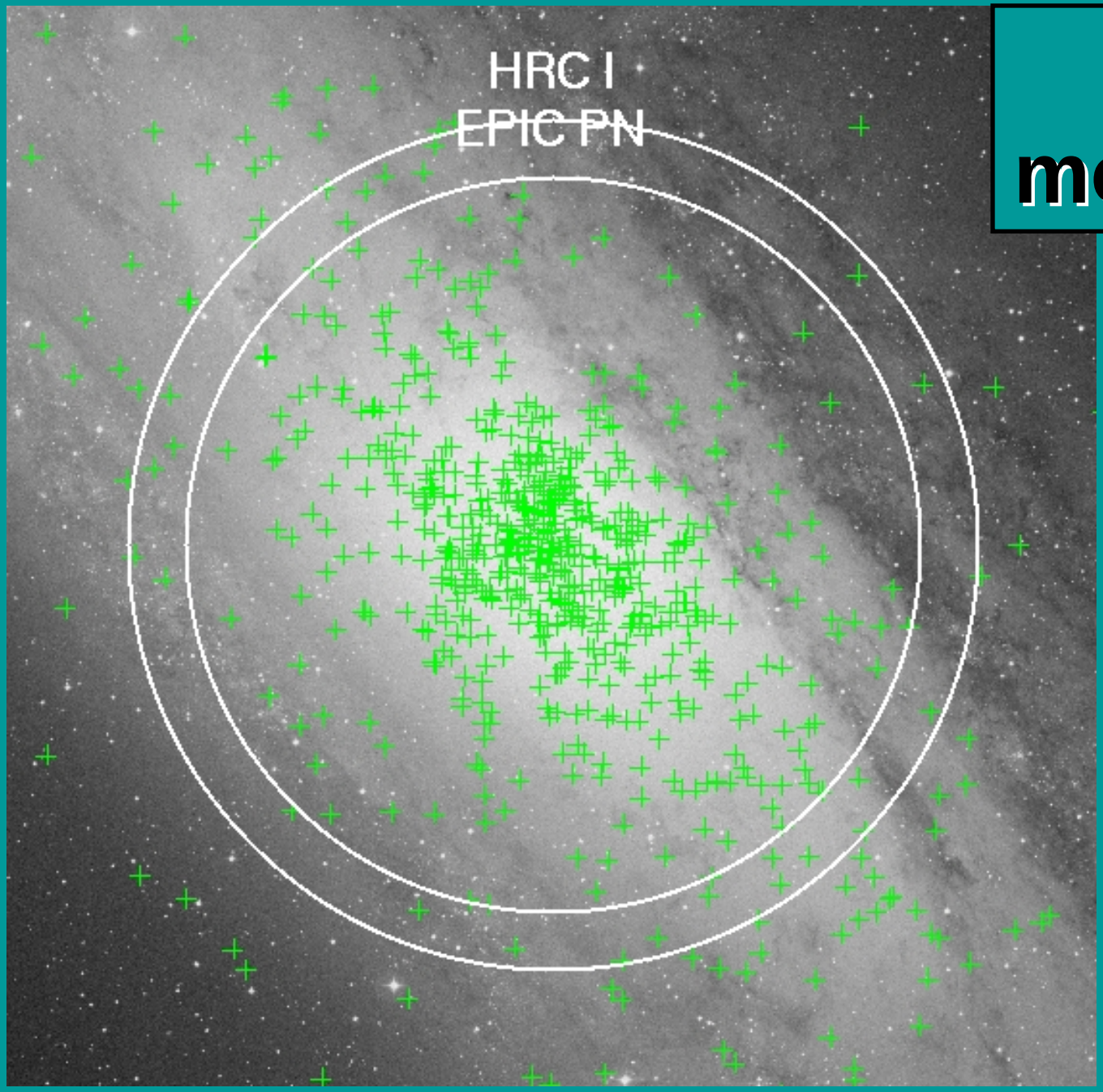


Period 1105 s
"dips" in 3 obs.

CV with magnetic massiv WD
"Intermediate polar?"

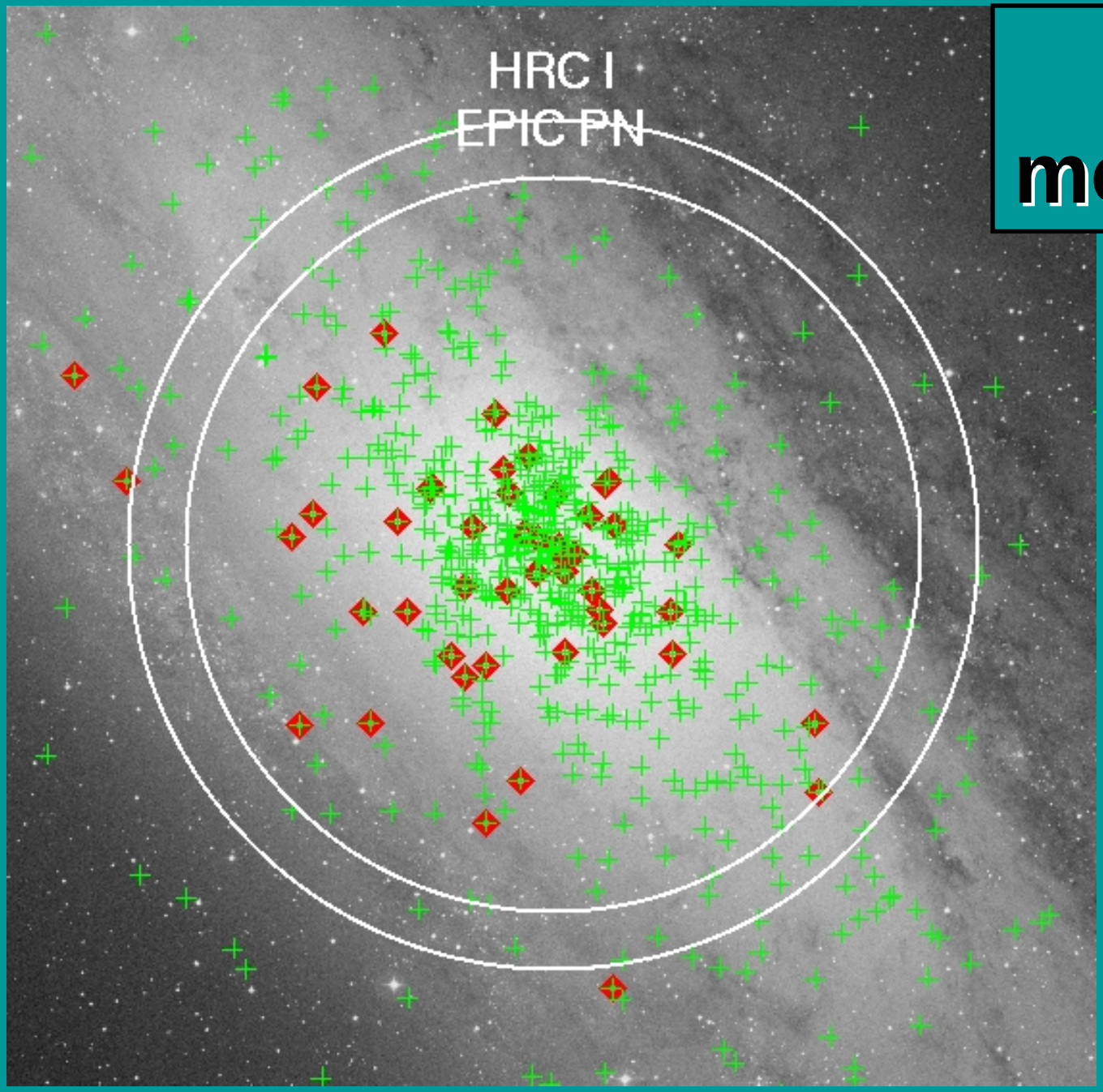
Similar to 865 s pulsating SSS detected with XMM-Newton in June 2000
(no nova counterpart known)

Osborne et al. 2001, A&A 378, 800



M 31 monitoring

Optical novae over-plotted

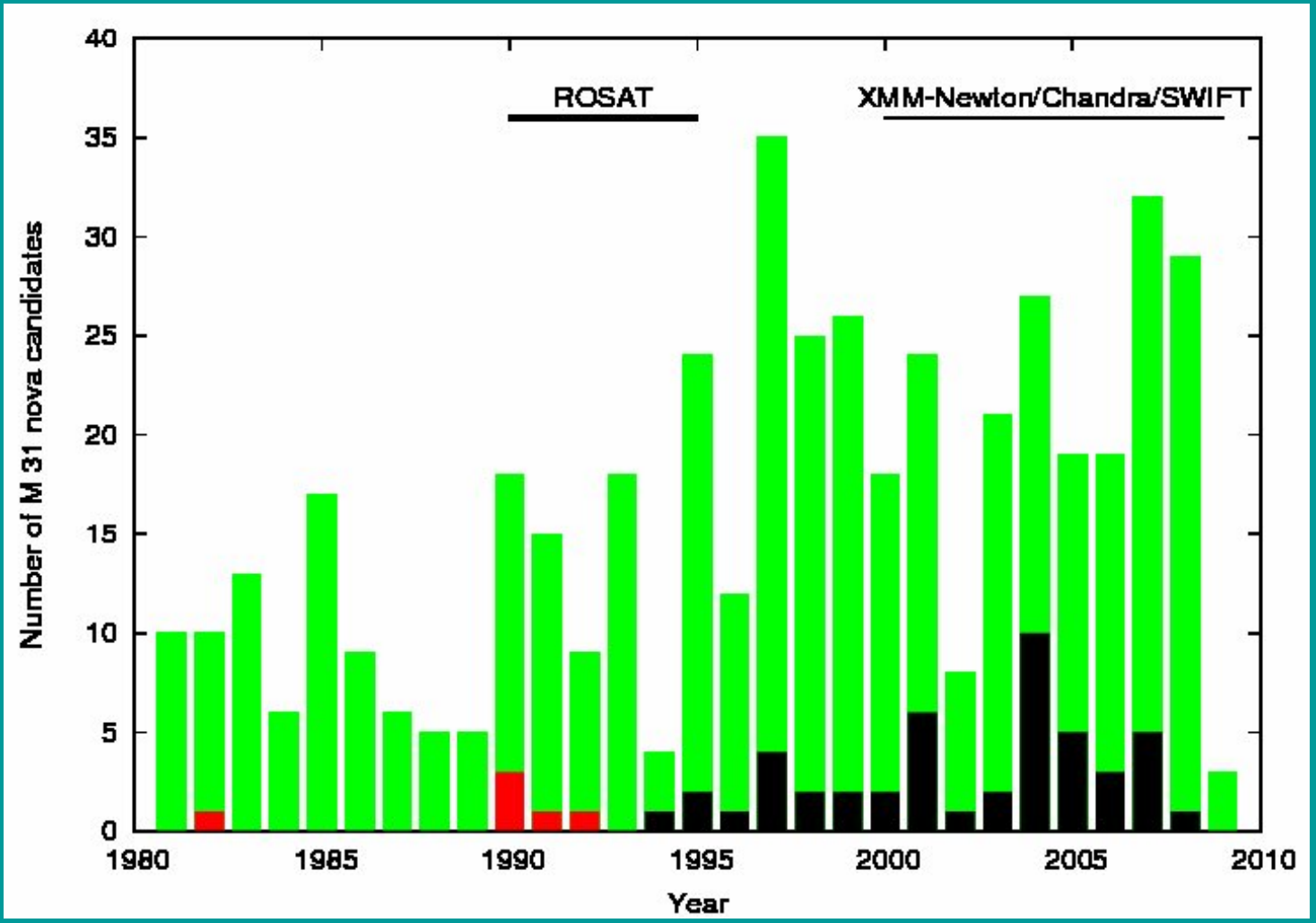


M 31 monitoring

Optical novae over-plotted

X-ray novae over-plotted

Optical novae in M31 and X-ray detections



Nova statistic in Local Group galaxies

	opt.novae total	novae/year 2000-2008	SSS detected
Galaxy	391	~8	~10
LMC	39	0.7	3
SMC	17	0.3	
M 31	816	22	53
M 32	3	0.2	
NGC 205	4	0.1	
M 33	32	0.5	2

Outlook

- Observations and analysis
  - Optical monitoring for M 31 novae continues after sun block end of May 2009
  - Classify as many M 31 novae as possible by optical spectra
  - XMM-Newton/Chandra monitoring of M 31 center from Nov 2009 to Feb 2010 secured
  - Improved positions of “Rosino” novae
  - Continue monitoring in AO9?
- Comparison M 31 to Galactic nova research
  - Light curves of SSS states – deep observations of individual novae (high resolution spectra, high time resolution)
  - Higher probability to find rare objects in M 31
  - Determine ejected, burning and White Dwarf masses for as many M 31 novae as possible
- X-ray results of last years proved importance of M 31 nova monitoring