# Recent Highlight SSS Discoveries in M 31

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# Context

We conducted a X-ray monitoring of M 31 for supersoft X-ray sources (SSSs) with XMM-Newton and Chandra

Three monitoring campaigns (AO5, AO6, AO7):
- 06 2006 – 03 2007, 11 2007 – 02 2008, 11 2008 – 02 2009
- different monitoring philosophies

Results from data reduction and source detection:
- 6 novae in AO5, 10 novae in AO6, 5 novae in AO7
- some novae in more than 1 AO, some in just 1 observation

Summarising papers are in preparation and will be out soon!

# *Highlights*

- First two transient SSSs in M 31 Globular Clusters

  → *Henze et al. 2009a, A&A, in press*

- Very short SSS state of nova M31N 2007-11a

  → *Henze et al. 2009b, A&A, 498, L13*

- Short time variability in SSS light curve of nova M31N 2006-04a

  → *Out soon: Henze et al. 2009c, in prep.*

# Transient SSSs in M 31 Globular Clusters



## The first two transient supersoft X-ray sources in M 31 globular clusters and the connection to classical novae⋆

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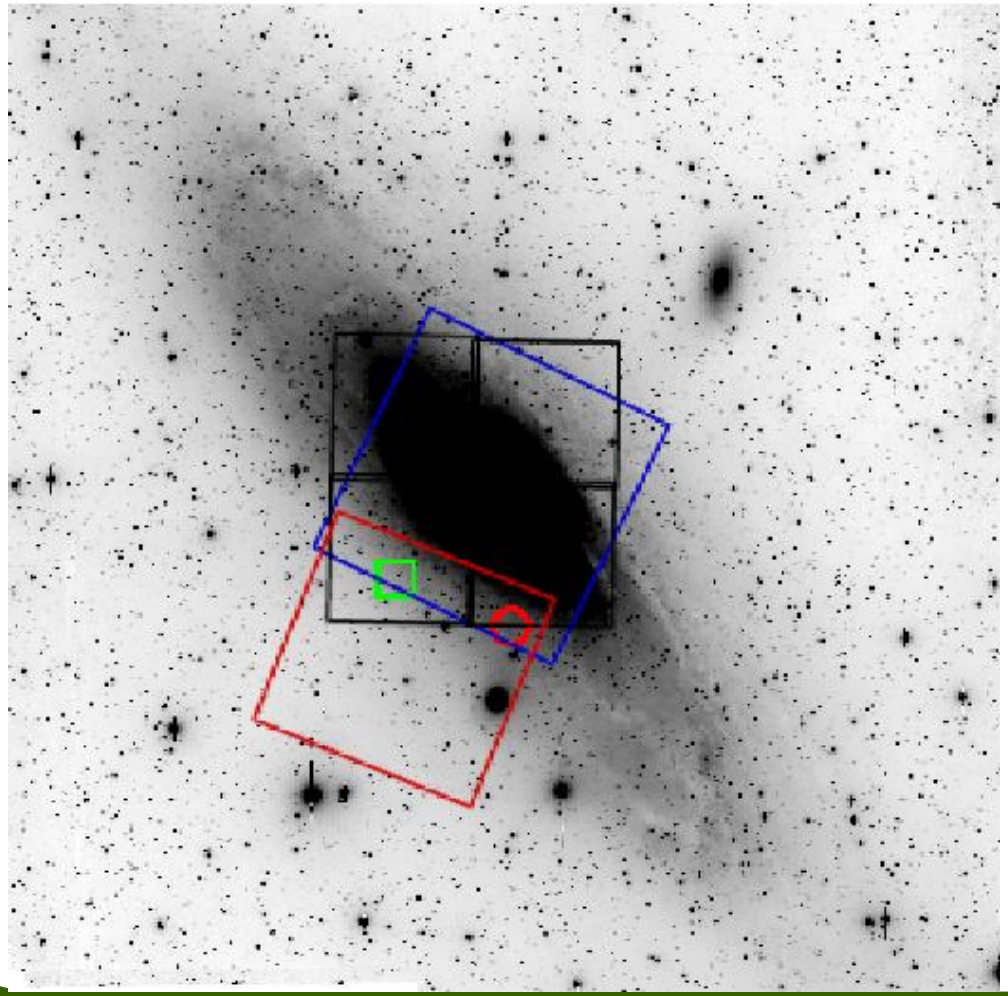
**ABSTRACT**

*Context.* Classical novae (CNe) have been found to represent the major class of supersoft X-ray sources (SSSs) in our neighbour galaxy M 31.
*Aims.* We determine the properties and evolution of the two first SSSs ever discovered in the M 31 globular cluster (GC) system.
*Methods.* We have used XMM-Newton, *Chandra* and *Swift* observations of the centre region of M 31 to discover both SSSs and to determine their X-ray light curves and spectra. We performed detailed analysis of XMM-Newton EPIC PN spectra of the source in Bol 111 (SS1) using blackbody and NLTE white dwarf (WD) atmosphere models. For the SSS in Bol 194 (SS2) we used optical monitoring data to search for an optical counterpart.
*Results.* Both GC X-ray sources were classified as SSS. We identify SS1 with the CN M31N 2007-06b recently discovered in the M 31 GC Bol 111. For SS2 we did not find evidence for a recent nova outburst and can only provide useful constraints on the time of the outburst of a hypothetical nova.
*Conclusions.* The only known CN in a M 31 GC can be identified with the first SSS found in a M 31 GC. We discuss the impact of our observations on the nova rate for the M 31 GC system.

**Key words.** Galaxies: individual: M 31 – novae, cataclysmic variables – stars: individual: Nova M31N 2007-06b – globular clusters, individual: Bol 111, Bol 194 – X-rays: galaxies

# *Transient SSSs in M 31 Globular Clusters (1)*

We discovered two new transient SSSs in November 2007 in the M 31 globular clusters (GCs) Bol 111 and Bol 194



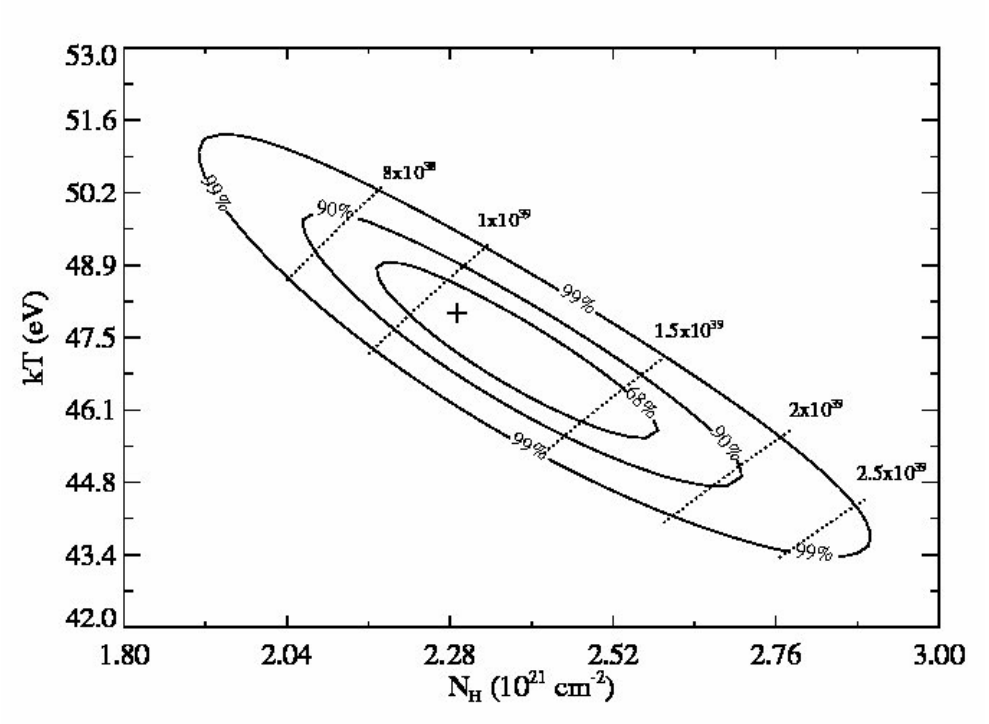
**First SSSs in M 31 GCs!**

Just one other SSS in a GC known before!
(1E 1339.8+2837 in the galactic GC M 3, see *Dotani et al. 1999, PASJ 51, 519*)

ROTSE-III optical image + X-ray and optical telescope fields:
**blue**: *Chandra* HRC-I
**red**: XMM-Newton PN
**black**: Super-LOTIS (optical)
**green square**: Bol 194
**red circle**: Bol 111

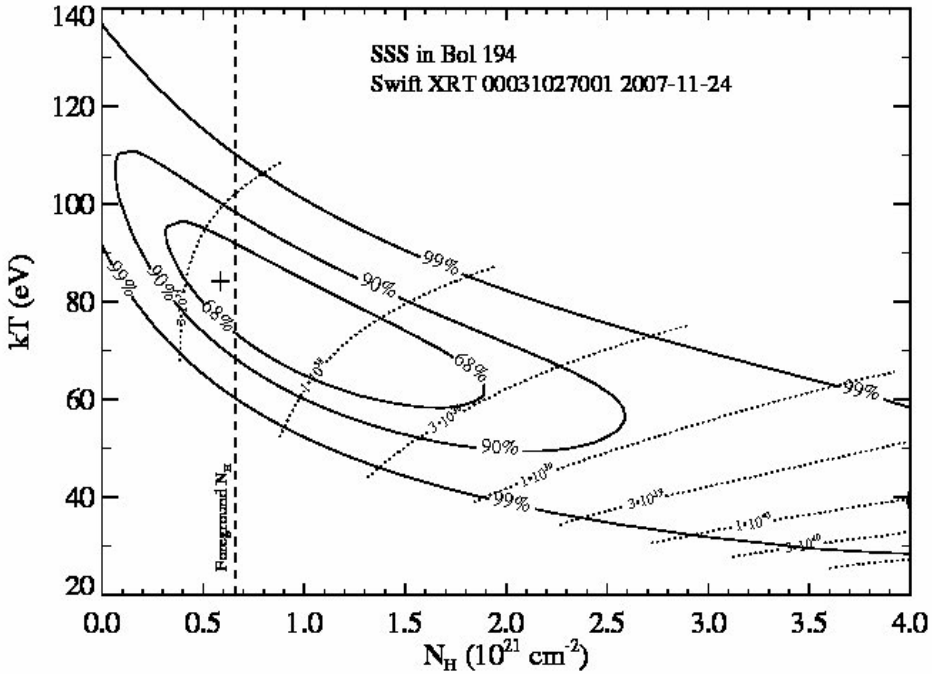
# *Transient SSSs in M 31 Globular Clusters (2)*

Confidence contours of blackbody fit to two XMM-Newton EPIC PN spectra of SS1 in Bol 111



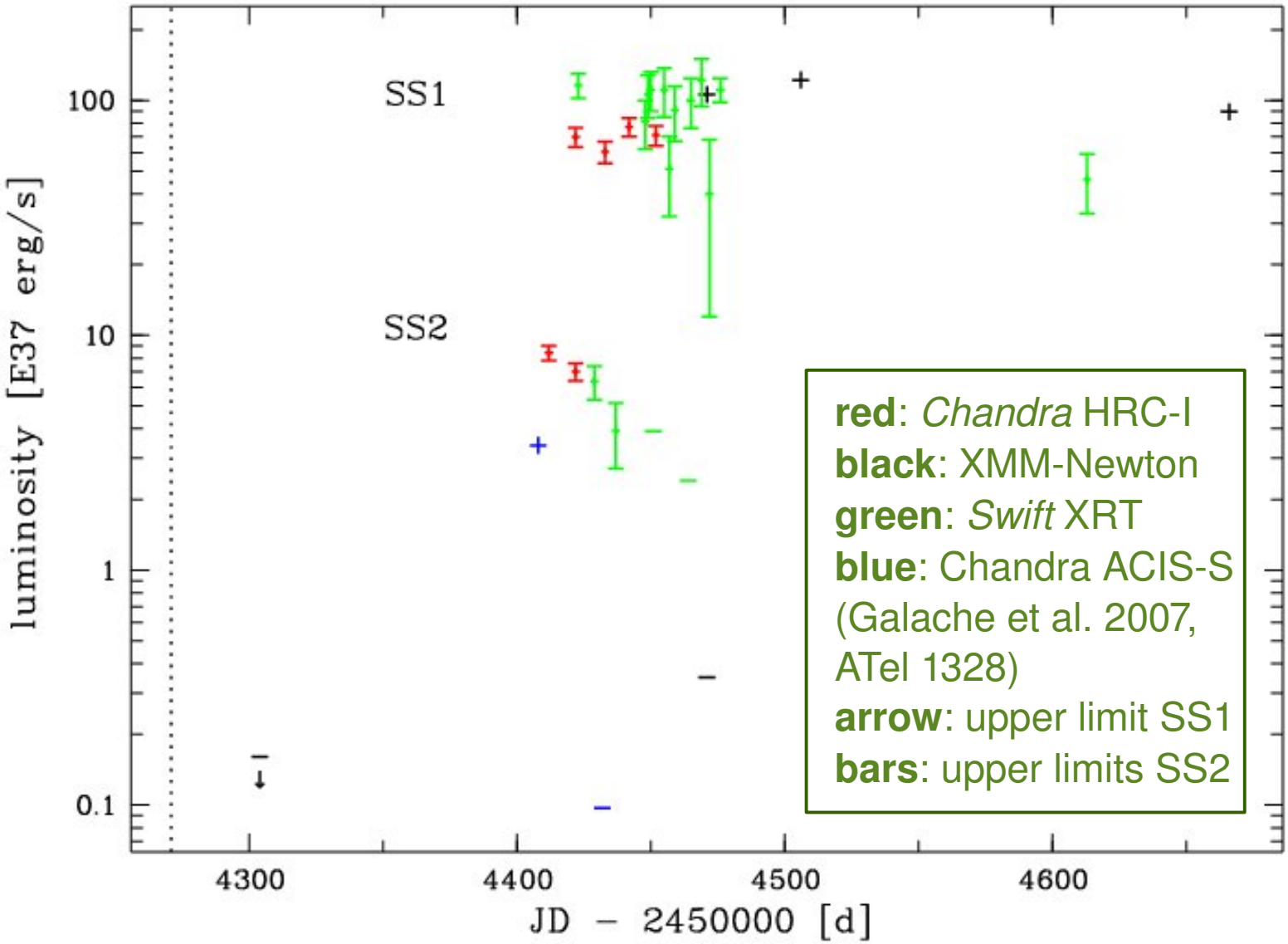

**cross** : Best fit values

Confidence contours of blackbody fit to Swift XRT spectrum of SS2 in Bol 194




**cross** : Best fit values

# *Transient SSSs in M 31 Globular Clusters (3)*



# *Transient SSSs in M 31 Globular Clusters (4)*

June 2007: Discovery of nova M31N 2007-06b, the very first nova in a M 31 GC, by *Shafter & Quimby (2007, ApJ 671, 121)* in Bol 111

Just two other likely candidates for novae in GCs known before! (see *Shara et al. 2004, ApJ, 605, L117*)

About 150 d time lag between nova outburst and first detection of SS1 in X-rays

→ Offsets like this observed for other supersoft nova counterparts *(Pietsch et al. 2007, A&A, 465, 375)*

**Due to the position, time lag and the spectrum of the X-ray source we identify SS1 with M31N 2007-06b**

# *Transient SSSs in M 31 Globular Clusters (5)*

***What about SS2? Can it also be identified with an optical nova?***

No optical nova reported for BoI 194. --> We searched our optical monitoring data for an outburst in BoI 194.

Based on observations obtained with:

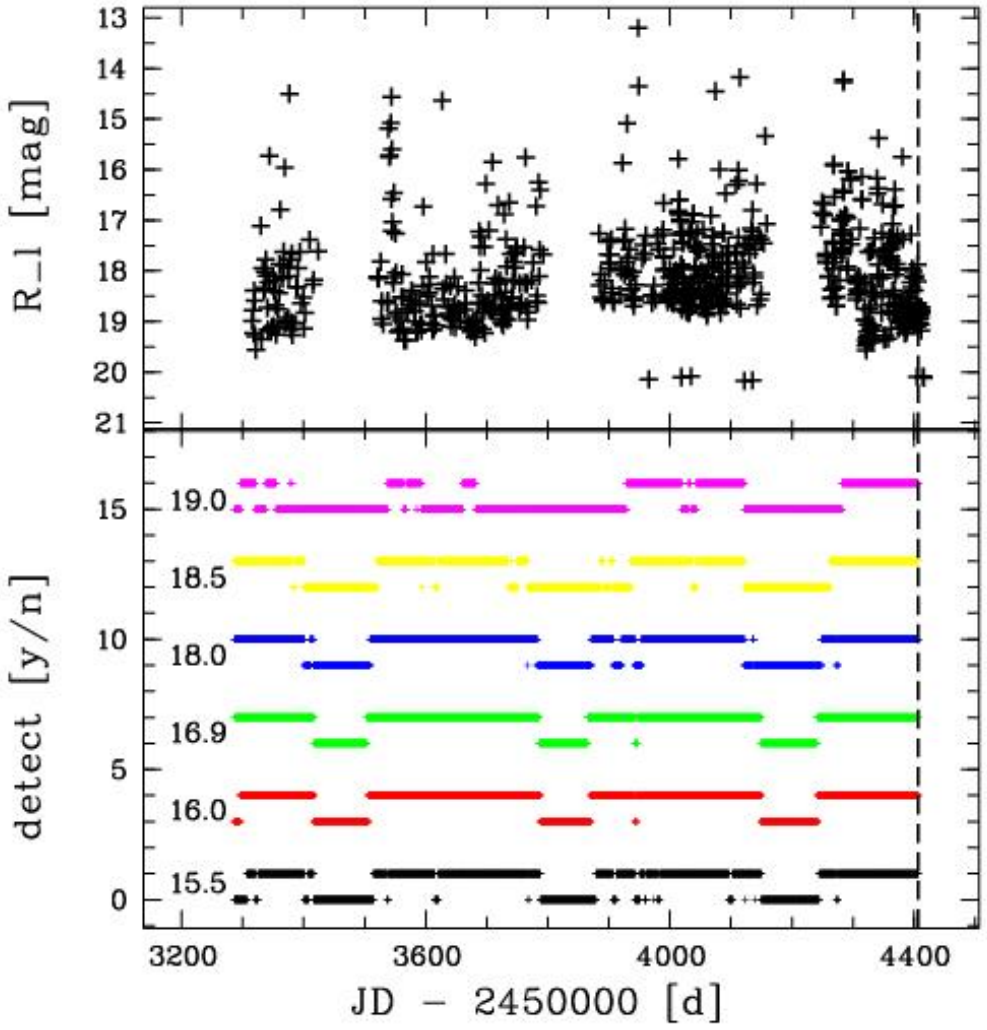
- ROTSE-IIId @ Turkish National Observatory, Bakirlitepe, Turkey (45 cm)
- Super-LOTIS @ Steward Observatory, Kitt Peak, Arizona, USA (60 cm)
- Telescopes at Lelekovice (35 cm) and Ondrejov (60 cm) observatories, Czech Republic

# *Transient SSSs in M 31 Globular Clusters (6)*

We found no evidence for a nova outburst in Bol 194.

But we can put useful constraints on the peak magnitude and outburst date of a hypothetical nova:

**Top**: limiting magnitudes of all optical data since 2004 November.
**Bottom**: simulated detection (upper points) or non-detection (lower points) for novae with given peak magnitudes.
**Dashed line**: first detection of SS2.



# Very short SSS state of M31N 2007-11a

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Astronomy & Astrophysics

LETTER TO THE EDITOR

## The very short supersoft X-ray state of the classical nova M31N 2007-11a⋆,⋆⋆

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**ABSTRACT**

*Context.* Short supersoft X-ray source (SSS) states (durations ≤100 days) of classical novae (CNe) indicate massive white dwarfs that are candidate progenitors of supernovae type Ia.
*Aims.* We carry out a dedicated optical and X-ray monitoring program of CNe in the bulge of M 31.
*Methods.* We discovered M31N 2007-11a and determined its optical and X-ray light curve. We used the robotic Super-LOTIS telescope to obtain the optical data and XMM-Newton and *Chandra* observations to discover an X-ray counterpart to that nova.
*Results.* Nova M31N 2007-11a is a very fast CN, exhibiting a very short SSS state with an appearance time of 6–16 days after outburst and a turn-off time of 45–58 days after outburst.
*Conclusions.* The optical and X-ray light curves of M31N 2007-11a suggest a binary containing a white dwarf with $M_{\rm WD} > 1.0\ M_{\odot}$.

**Key words.** galaxies: individual: M31 – novae, cataclysmic variables – stars: individual: nova M31N 2007-11a – X-rays: galaxies

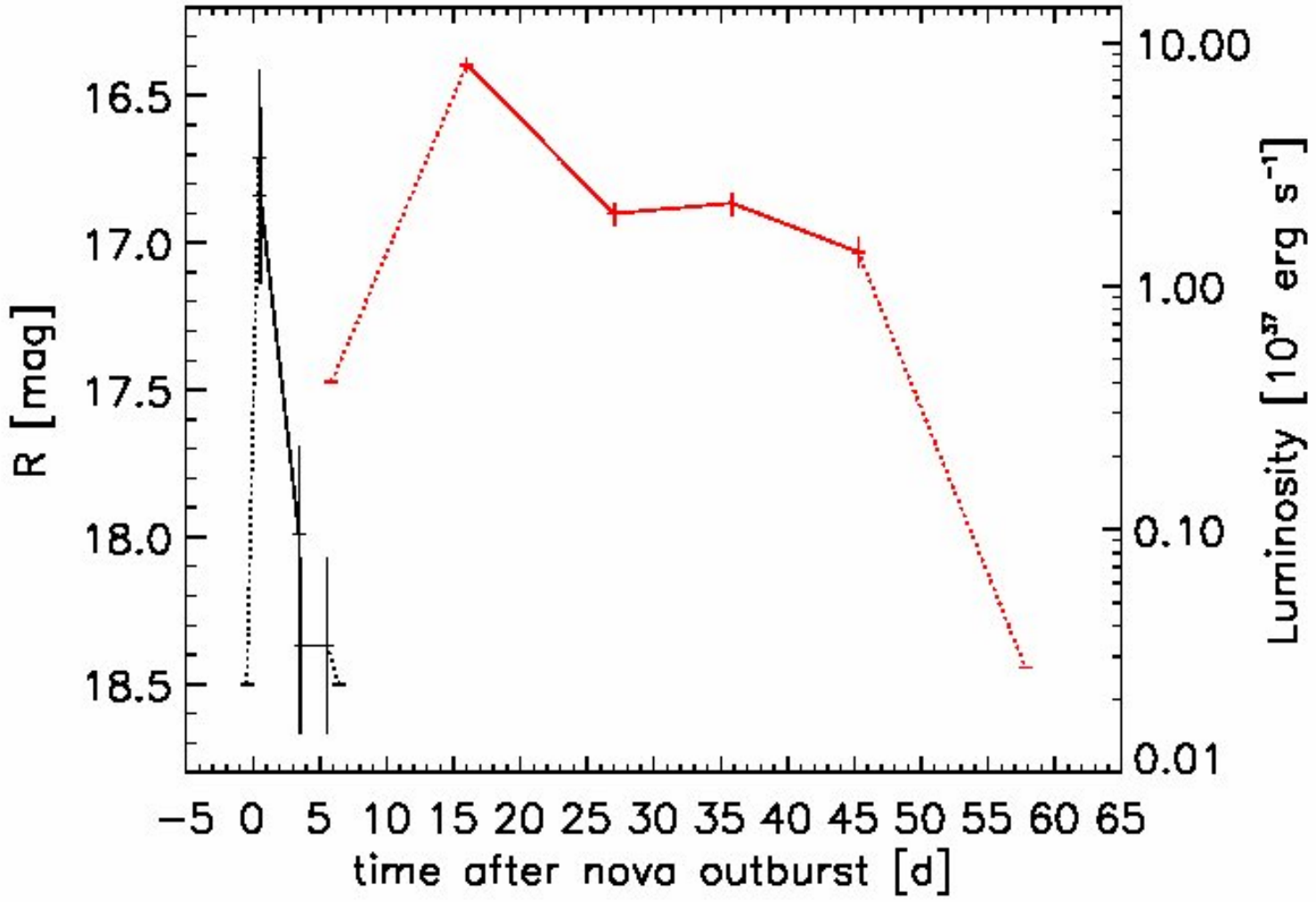
# *Very short SSS state of M31N 2007-11a (1)*

*Pietsch et al. (2007)*: Novae with short SSS states (< 100 d) seem to be more common than expected

We modified our monitoring strategy for SSS nova counterparts in M 31: single observations separated by 10 d in AO6/AO7 instead of 1.5 months as in AO5

# *Very short SSS state of M31N 2007-11a (2)*

Optical (black) and X-ray (red) light curve of M31N 2007-11a



# *Very short SSS state of M31N 2007-11a (3)*

Appearance time of SSS: 6 – 16 d after optical outburst

→ Ejected mass = (0.4 – 3) x 10^(-7) solar masses

→ Two orders of magnitude lower than typical ejected masses of other M 31 novae (*Pietsch et al. 2007*)

Turn-off time of SSS: 45 – 58 d after optical outburst

→ Burned mass = (8 – 10) x 10^(-8) solar masses

! Typical values for expansion velocity, bolometric luminosity and hydrogen mass function used !

# *Very short SSS state of M31N 2007-11a (4)*

Short SSS phase can have been caused by:

- White dwarf with mass > 1.1 solar masses & standard hydrogen fraction in the envelope
- White dwarf with mass ~ 1.0 solar masses & very hydrogen-poor envelope

White dwarf mass estimate from the optical light curve (following *Livio 1992, ApJ, 393, 516* ) and from the tables in the work of *Hachisu & Kato (2006, ApJS, 167, 59* ) are in the same range

# *M31N 2006-04a - variable SSS light curve*

First highlight of paper in preparation:

"***X-ray monitoring of Classical Novae in M 31 from June 2006 to March 2007*** "

→ Summary of results from XMM-Newton/ Chandra AO5 campaign

→ 6 X-ray counterparts of CNe in total

# *M31N 2006-04a - variable SSS light curve (1)*

M31N 2006-04a

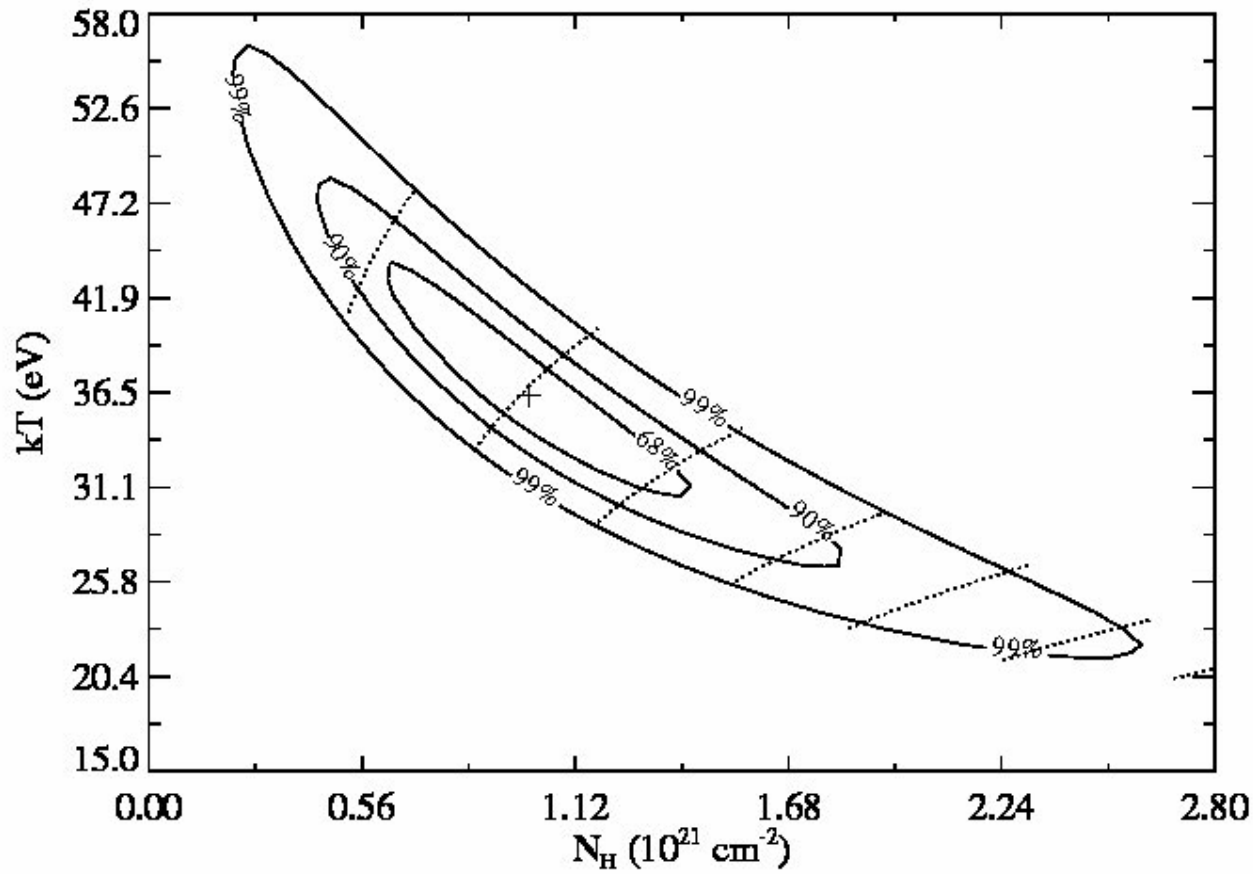
Independently discovered by *Pietsch et al. (2006, ATel #805; our optical monitoring of M 31)* and *Koichi Itagaki, Japan*

First optical detection on 2006-04-28; maximum magnitude 15.9 (unfiltered); no t_2, t_3 or spectrum known

First and only X-ray detection on 2006-08-09, 103 days after the optical discovery with XMM-Newton; not visible on 2006-07-02 (XMM) and 2006-09-30 (Chandra)

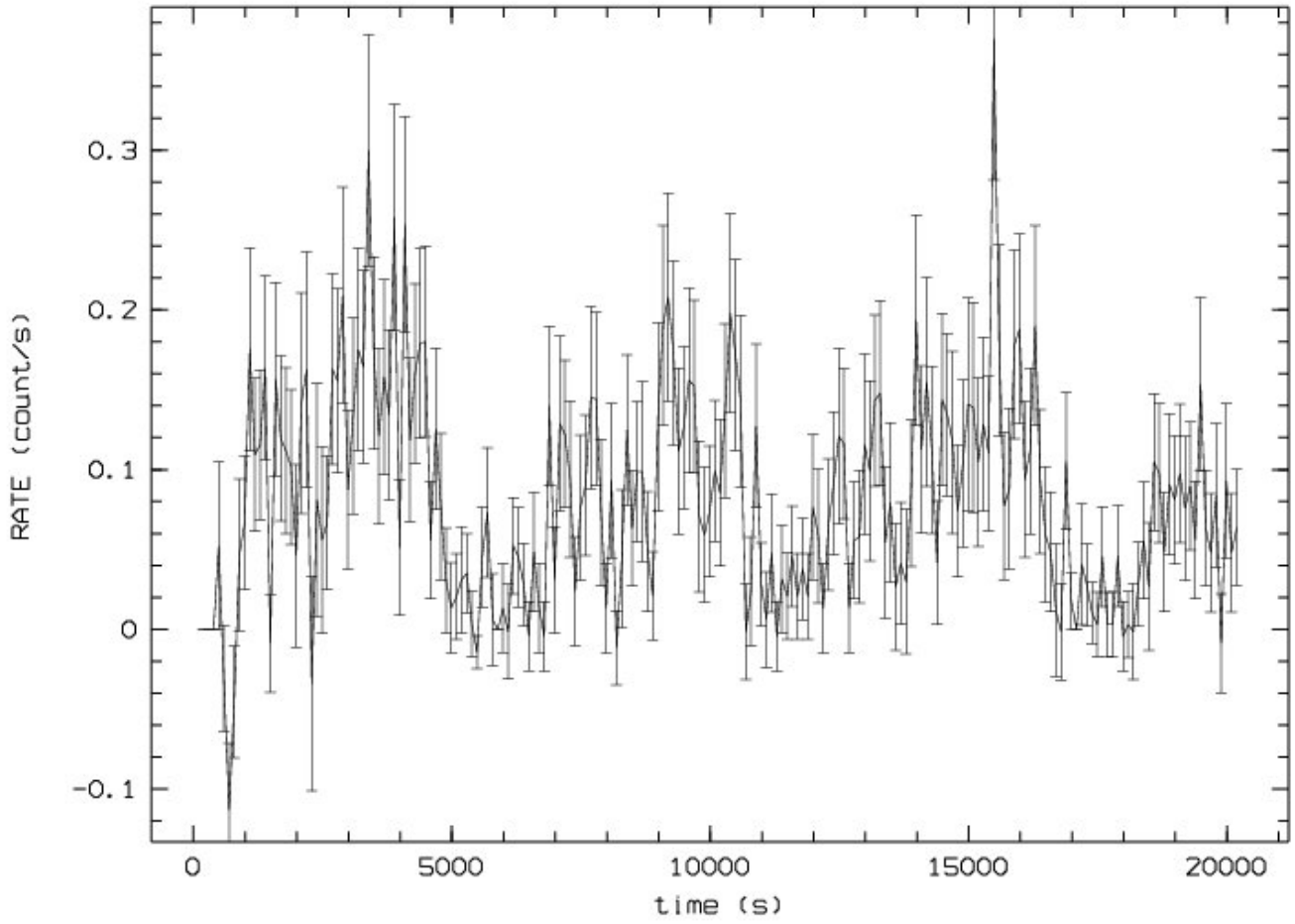
# *M31N 2006-04a - variable SSS light curve (2)*

Best Fit for EPIC PN spectrum of M31N 2006-04a:
blackbody with kT = 36 eV and N_H = 0.9E21 cm^(-2)
(foreground N_H = 0.7E21 cm^(-2))



# *M31N 2006-04a - variable SSS light curve (3)*

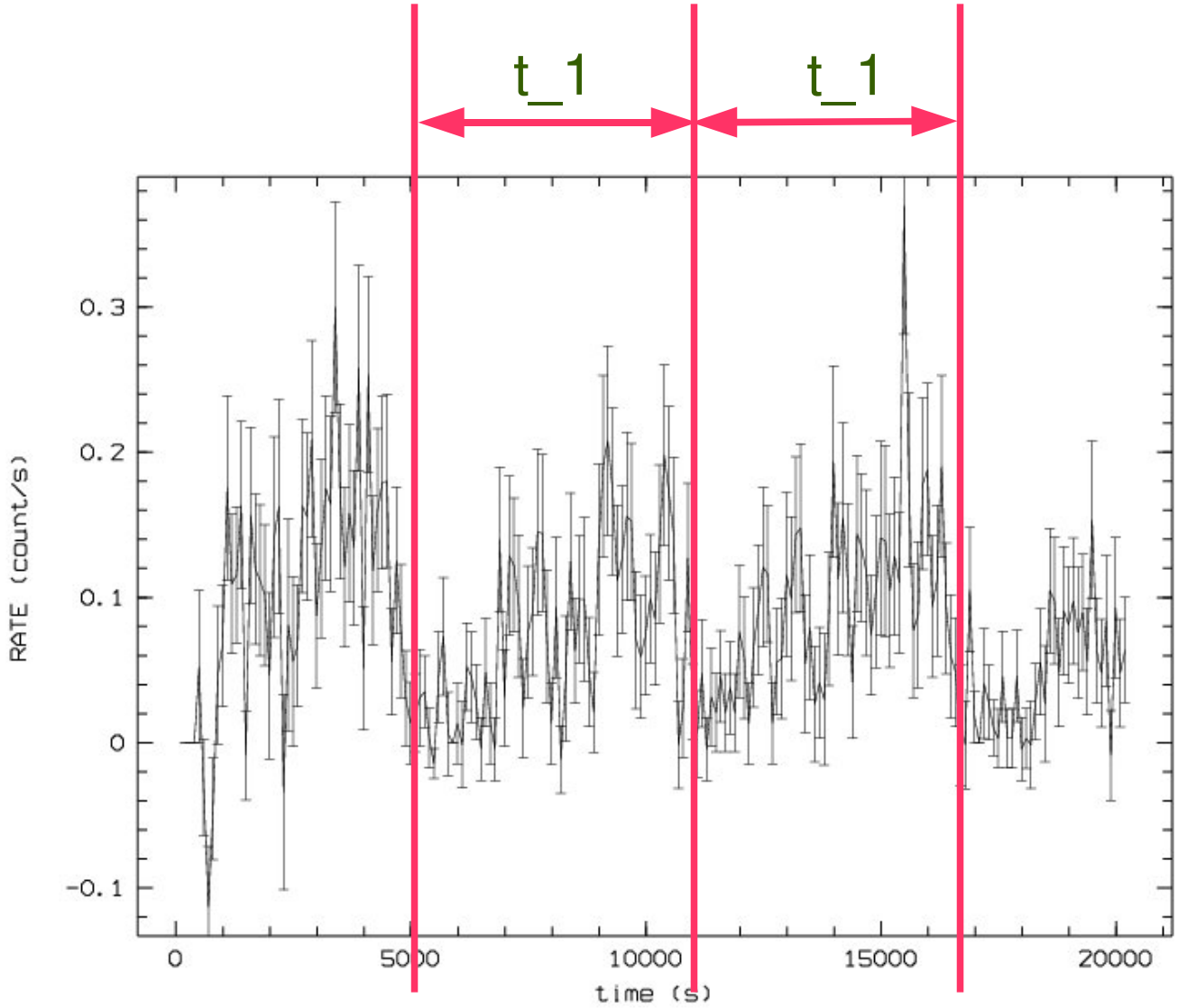
Background-corrected EPIC PN light curve; 100 s bins:



# M31N 2006-04a - variable SSS light curve (4)

t_1 = 1.9 h

indications of
a periodicity



# *M31N 2006-04a - variable SSS light curve (5)*

Three SSSs with period known in M 31:

- M31N 2007-12b: 1105 s period (*talk by W. Pietsch* )

- XMMU J004319.4+411758: 865.5 s pulsation period, transient source, no confirmed CN (*Osborne et al. 2001, A&A, 378, 800* )

- XMMU J004252.5+411540: 217.7 s pulsation period, persistent source (*Trudolyubov & Priedhorsky 2008, ApJ, 676, 1218* )

# *M31N 2006-04a - variable SSS light curve (6)*

Orbital periods of Cataclysmic Variables typically in the range of 1 – 10 h (*Ritter & Kolb 2003, A&A, 404, 301*), CNe have similar orbital periods (*Warner 2002, AIP Conf. Proc. 637*)

Pulsation and spin periods of Wds in CNe are typically shorter; see e.g. *Drake et al. 2003, ApJ, 584, 448* :
2500 s period pulsations in nova V1494 Aql

# *Summary & Outlook*

Results so far from the recent XMM-Newton/Chandra monitoring observations of M 31:

- First SSSs in M 31 GCs (connection to first M 31 GC nova)
- Very short SSS phase of nova M31N 2007-11a
- Short time SSS flux variability of nova M31N 2006-04a

In preparation: summarising papers on all SSS counterparts of optical novae found in the M 31 central region in AO5/AO6/AO7