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

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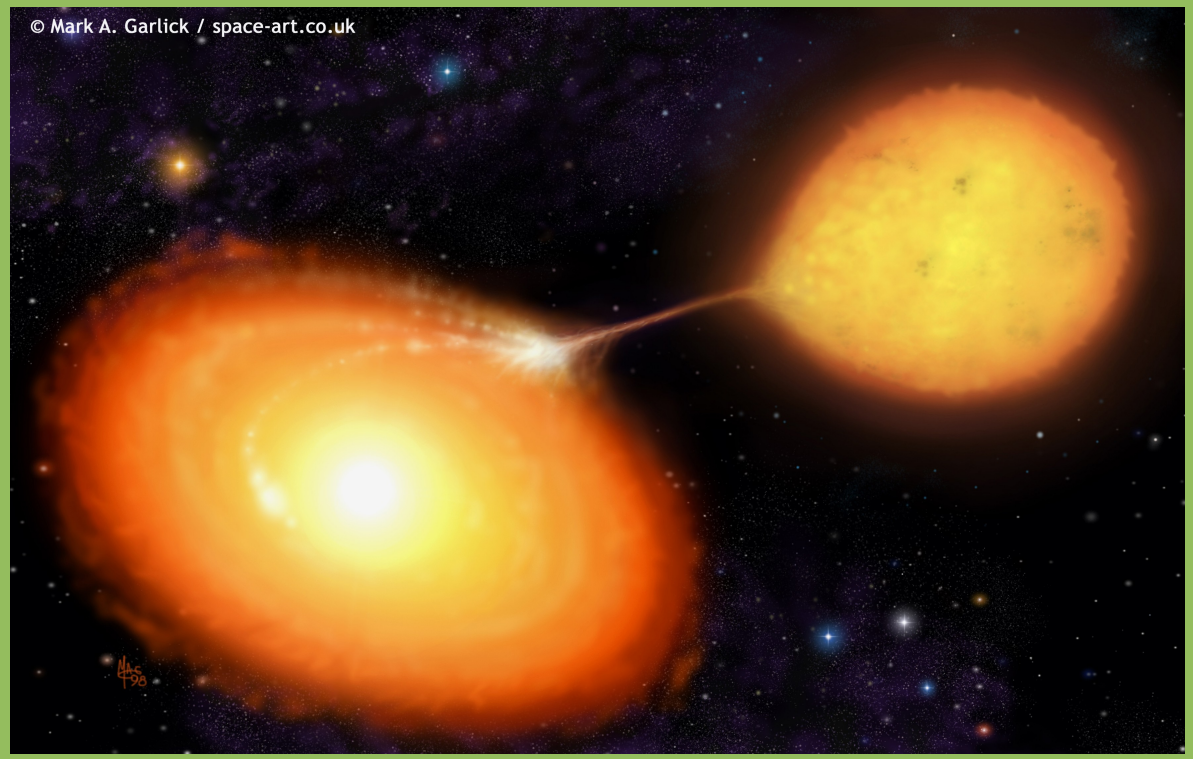
Introduction: Optical novae and supersoft X-ray sources (1)

Optical nova:

- Thermonuclear explosion on the surface of a White Dwarf (WD) in a cataclysmic binary system

- Hydrogen rich matter is accumulated on the WD's surface until hydrogen ignition conditions are reached --> thermonuclear runaway --> expansion of hot envelope leads to increase of optical luminosity (= nova outburst)



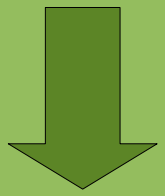
Introduction: Optical novae and supersoft X-ray sources (2)

- But: a fraction of the hot envelope can remain in steady hydrogen burning on the WD's surface

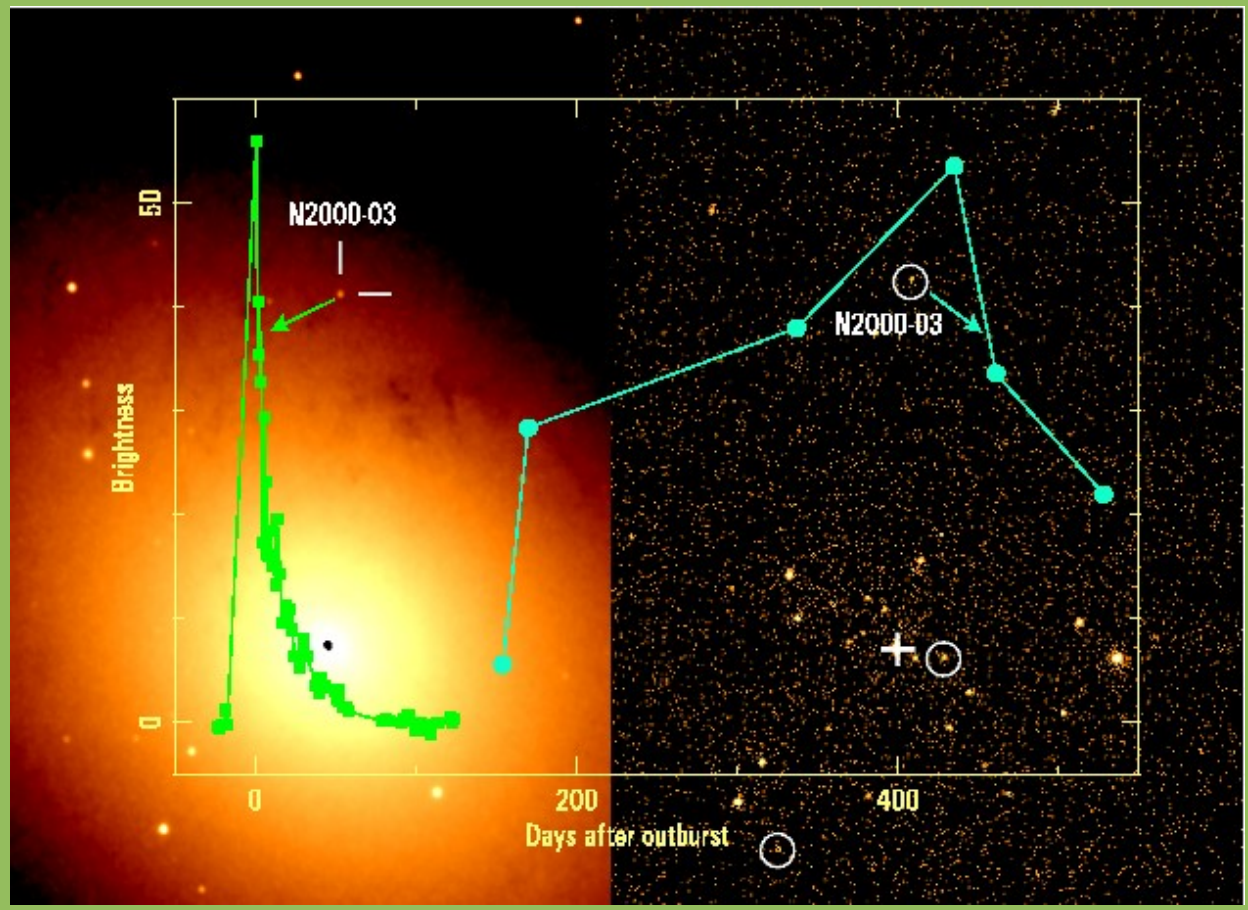
- This powers a supersoft X-ray source (SSS) which can be observed as soon as the ejected envelope becomes optical thin enough

- SSS: no emission above 1keV, blackbody fits with kT < 80 – 100 eV

- SSS phase of novae is much longer than the time of optical visibility



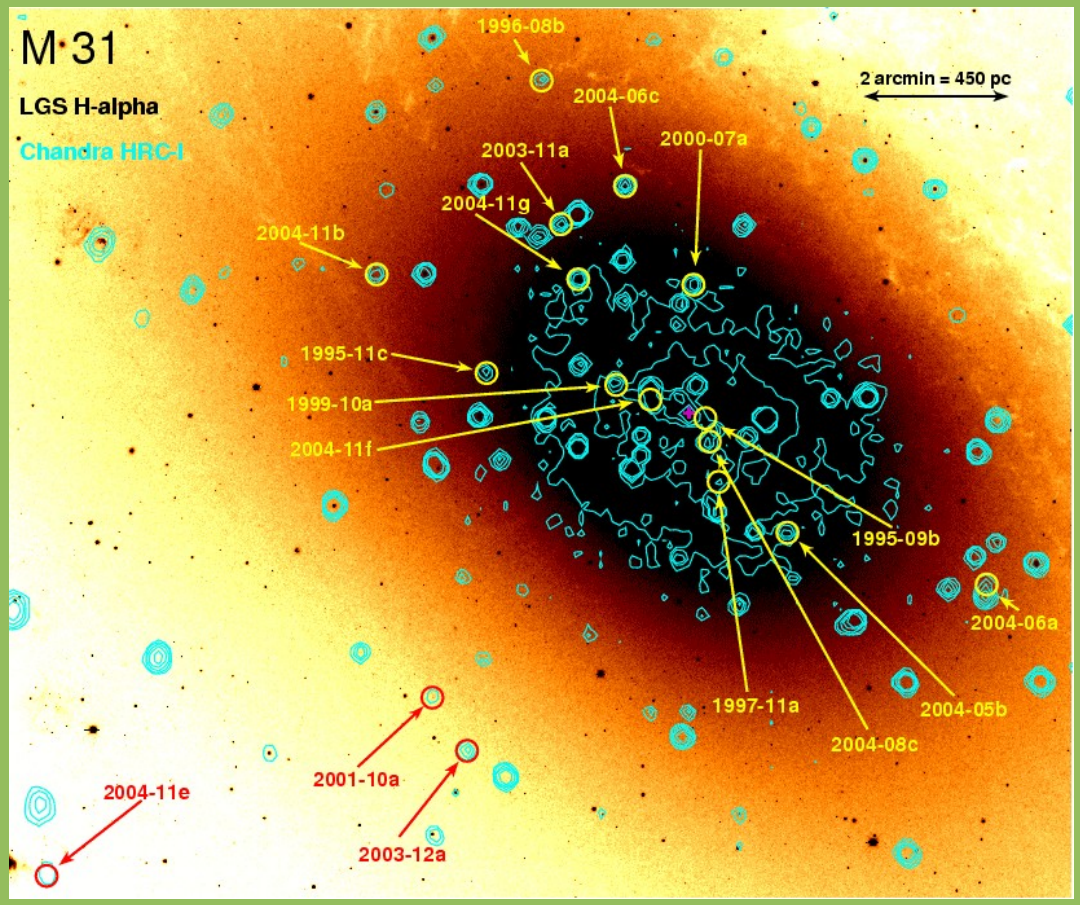
X-ray observations can help to discover optical novae



Introduction: Optical novae and supersoft X-ray sources (3)

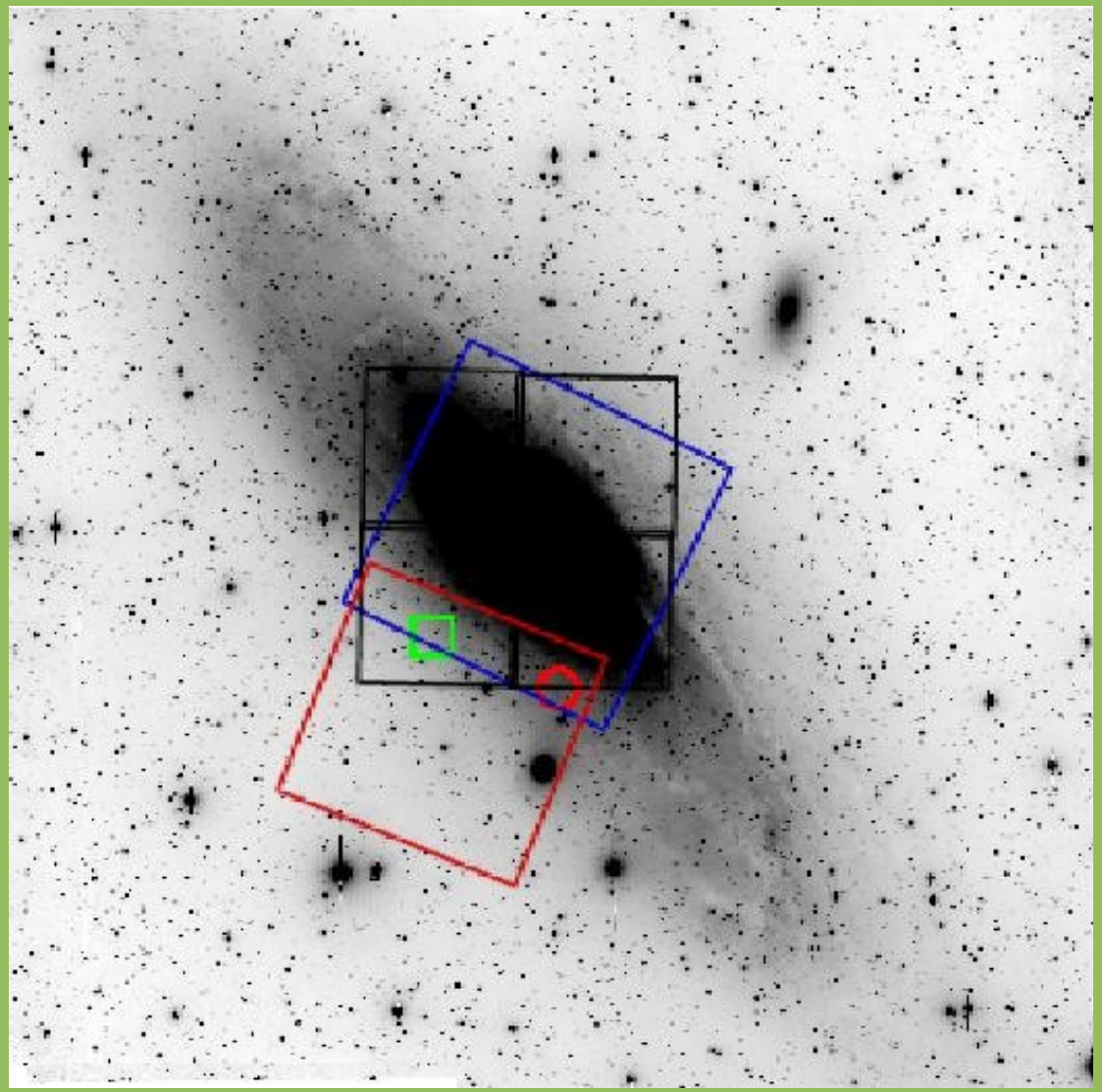
- Pietsch et al. (2005): optical novae are the major class of SSSs in the galaxy M 31 (distance 780kpc, *Stanek & Garnavich 1998, ApJ 503, L131*)

- Ongoing dedicated XMM-Newton/*Chandra* monitoring program for SSS in M 31 (PI: W. Pietsch); occasional *Swift* follow-up observations



Supersoft sources in M 31 globular clusters: positions

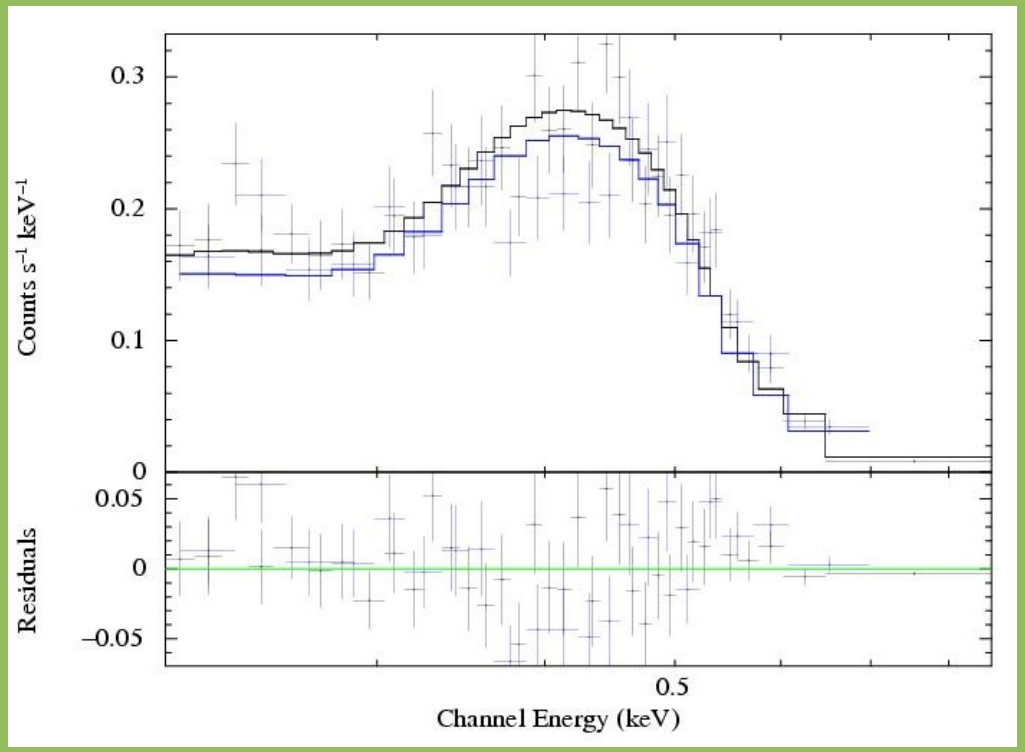
We discovered two new transient SSSs in November 2007 in M 31 globular clusters (GCs) Bol 111 and Bol 194



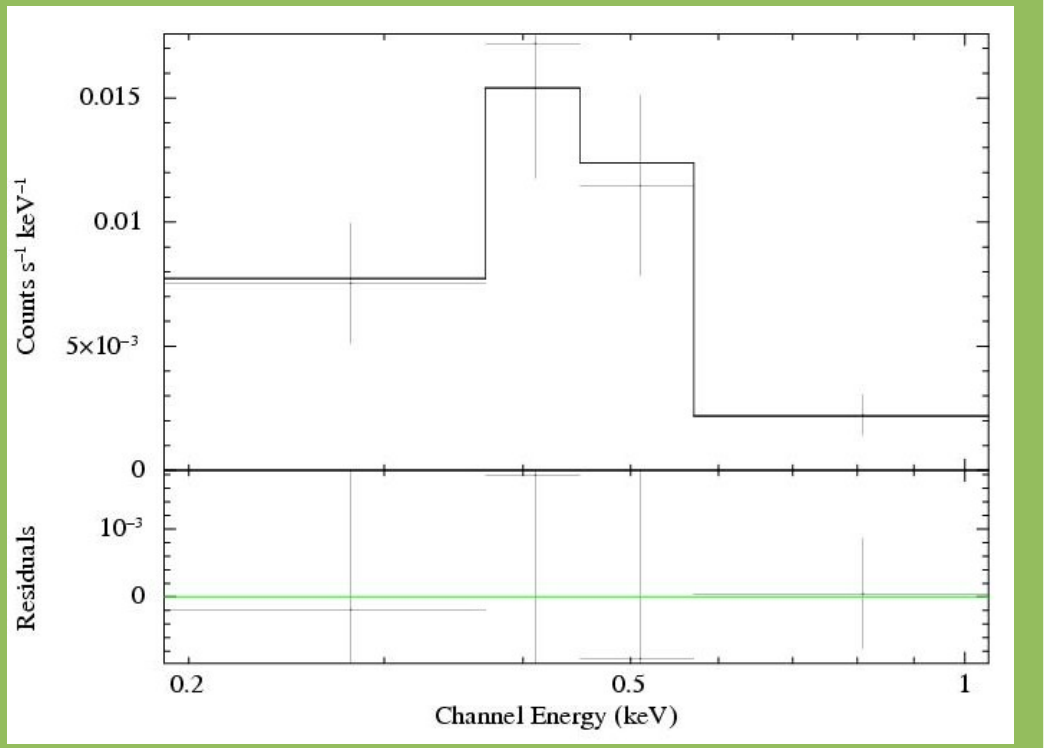
ROTSE-III optical image + X-ray and optical telescope fields:
blue: *Chandra* HRC-I
red: XMM-Newton PN
black: Super-LOTIS (optical)
green square: Bol 194
red circle: Bol 111

Supersoft sources in M 31 globular clusters: spectra

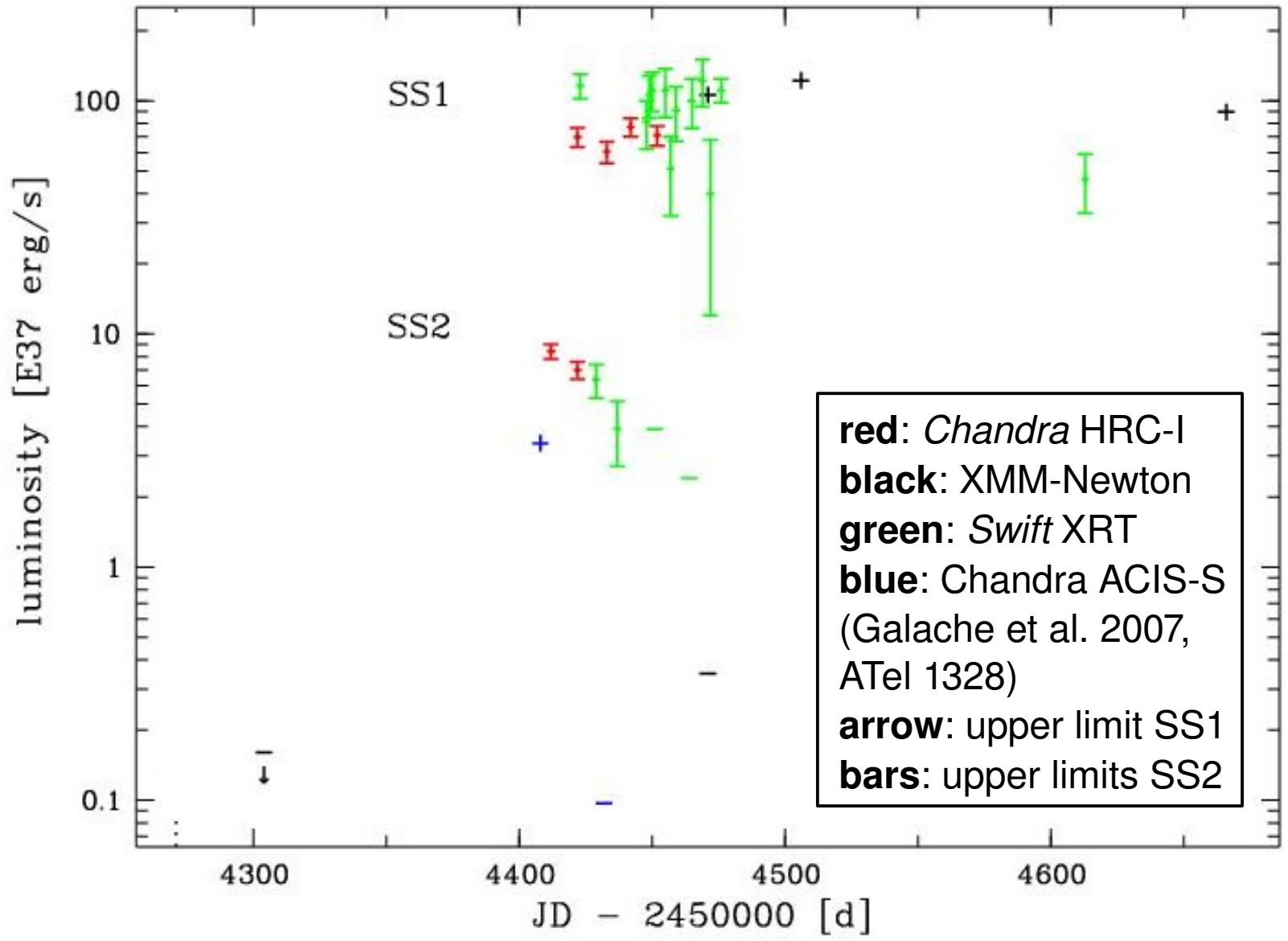
XMM-Newton EPIC PN spectra of SS1 in Bol 111 + blackbody fit: kT = 48 eV



Swift XRT spectrum of SS2 in Bol 194 + blackbody fit: kT = 74 eV

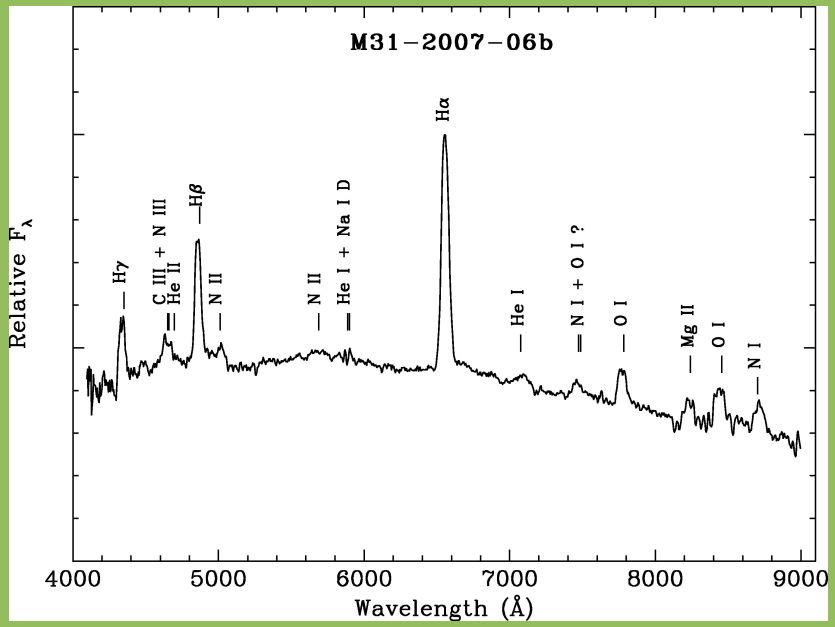


Supersoft sources in M 31 globular clusters: light curves



Connection of the supersoft sources to optical novae (1)

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



Spectrum from *Shafter & Quimby*:
- He/N nova in the system of *Williams 1992, AJ, 104, 725*

About 150 d time lag between nova outburst and first detection of SS1
--> offsets like this observed for other nova systems (Pietsch et al. 2007)

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

Connection of the supersoft sources to optical novae (2)

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

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

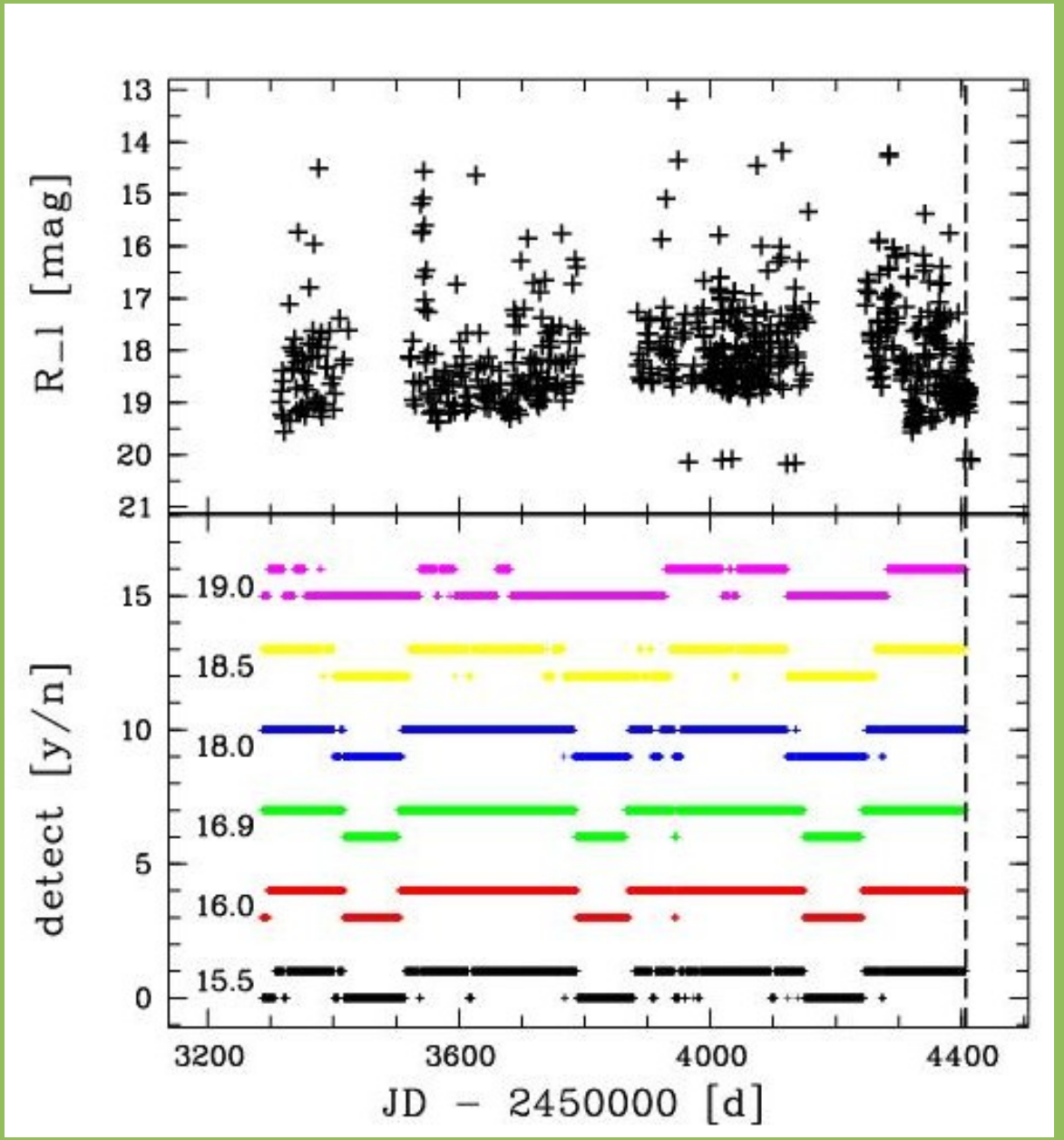
Based on observations obtained with:

- 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

Connection of the supersoft sources to optical novae (3)

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:

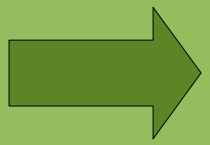


Top: limiting magnitudes of all optical data since 2004 November.
Bottom: simulated detection (upper points) or non-detection (lower points) for novae with given peak magnitudes.
Dashed line: first detection of SS2.

Connection of the supersoft sources to optical novae (4)

Assumption 1: SS2 was associated with an optical nova outburst

Assumption 2: Both novae have SSS durations of approx. 1 year



Rate of 0.015 novae per year per GC

Be careful! Small number statistics!

From stellar evolution: nova rate of 0.002 novae per year per GC

From optical M 31 surveys: upper limit on nova rate of
0.005 novae per year per GC (*Tomaney et al. 1992, BAAS, 24, 1237*)

Summary and Discussion

We discovered and characterized the first two SSSs in M 31 globular clusters and conducted follow-up photometry using XMM-Newton, *Chandra* and *Swift* observations.

> **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*)

One of the two sources we identify with M31N 2007-06b, the very first nova in a M 31 GC.

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

If SS2 was a post-nova **then** the nova rate for the M 31 GC system might be much larger than previously estimated from optical surveys and stellar evolution.

Better statistics is needed to study the SSS and nova rates in GCs! M 31 center monitoring is very efficient for finding SSS counterparts of optical novae!