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

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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 \( kT < 80 - 100 \text{ eV} \)

- 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 780 kpc, 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
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

- **Red**: Chandra HRC-I
- **Black**: XMM-Newton
- **Green**: Swift XRT
- **Blue**: Chandra ACIS-S
  
  (Galache et al. 2007, ATEL 1328)

- **Arrow**: upper limit SS1
- **Bars**: upper limits SS2

![Graph showing light curves of supersoft sources in M 31 globular clusters with annotations for different data sources and upper limits.](image-url)

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 (1)
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-IIIId @ 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
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!