New X-ray lights on the supernova remnant population of the LMC

Pierre Maggi (MPE Garching)

and the XMM-Newton LMC survey collaboration:

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J. Dickel (University of New Mexico)

The X-ray Universe 2014
Trinity College Dublin, Ireland

16 June 2014
OUTLINES

1 INTRODUCTION
Astrophysical relevance of SNRs
A (biased) comparison of Galactic vs. LMC observations

2 NEW SUPERNova REMNANTS IN THE LARGE MAGELLANIC CLOUD
The XMM-Newton survey of the LMC
Collection of new SNRs
Highlights: Old type Ia remnants

3 POPULATION STUDY
SNRs and Star Formation History
Population properties

4 SUMMARY
Introduction

Astrophysical relevance of SNRs N132D and DEM L71, two SNRs in the LMC (Chandra SNR catalog)

- Rest of a supernova, either type Ia or core-collapse.
- Shape, heat, enrich, and mix up the ISM.
- Efficient cosmic-ray accelerator.
- Can be used to probe the ISM (abundance/density).
- Provides details about explosion mechanisms (asymmetries, nucleosynthesis yields).

Observational signatures

- X-ray emission
- Non-thermal (synchrotron) radio emission
- Optical line; enhanced [Si]/H\alpha
- High-velocity gas (> 100 km s\(^{-1}\))

N132D and DEM L71, two SNRs in the LMC (Chandra SNR catalog)
Introduction

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### Introduction

(Biased) comparison of Galactic vs. LMC observations

<table>
<thead>
<tr>
<th></th>
<th>MW</th>
<th>LMC</th>
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<tbody>
<tr>
<td>Distance</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
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<tr>
<td>Absorption</td>
<td>$N_H \sim 10^{22} \text{ cm}^{-2}$</td>
<td>$N_H \lesssim 10^{21} \text{ cm}^{-2}$</td>
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**Graph**: 16 June 2014

**Spectrum**:
- $kT = 0.5$ keV
- $L_X = 10^{36}$ erg s$^{-1}$

**Elements**: O, Mg, Fe, Si, Ne, S

**X-ray**

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>Photons cm$^{-2}$ s$^{-1}$ keV$^{-1}$</th>
</tr>
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<tbody>
<tr>
<td>0.5</td>
<td>$10^{-7}$</td>
</tr>
<tr>
<td>1</td>
<td>$10^{-5}$</td>
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<tr>
<td>2</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>5</td>
<td>$10^{-1}$</td>
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## Introduction

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### Energy vs. Normalized Counts

- $N_H = 0 \text{ cm}^{-2}$
- $N_H = 10^{21} \text{ cm}^{-2}$
- $N_H = 3 \times 10^{22} \text{ cm}^{-2}$

- $kT = 0.5 \text{ keV}$
- $L_X = 10^{36} \text{ erg s}^{-1}$

XMM–Newton EPIC–pn

- Fe
- Mg
- Ne
- O
- Si
- S

Normalized counts s$^{-1}$ keV$^{-1}$

Energy (keV)
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**New Supernova Remnants in the Large Magellanic Cloud**
The XMM-Newton survey of the LMC
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**Population Study**
SNRs and Star Formation History
Population properties

**Summary**
New SNRs in the LMC

The XMM-Newton survey of the LMC

Data from MCELS (Smith et al. 2000)

[SII]  
Hα  
[OIII]

1.8 Ms VLP [PI: F. Haberl]

Review talk by F. Haberl  
Tuesday plenary at 11:00
New SNRs in the LMC

The XMM-Newton survey of the LMC

0.2 – 1 keV
1 – 2 keV
2 – 4.5 keV
1. Exclude point sources (background AGN, Galactic stars, XRBs).
2. Exclude non-SNRs extended sources:
   - Superbubbles (optically bright)
   - Galaxy clusters (hotter temperature)
   - Diffuse emission (easy to spot in mosaicked image)
3. Check that X-ray properties (size and soft emission) are indicative of a SNR.
4. Check that there are enough counts for a meaningful analysis.
New SNRs in the LMC

Collection of new SNRs

Maggi+ 2012

MCSNR J0508-6902

~23000 yr

Bozzetto+14

MCSNR J0506-7025

[HP99] 1139

17 - 21 kyr

Whelan+ in prep. (poster D06)

MCSNR J0511-6759

> 20000 yr ?

MCSNR J0508-6830

> 20000 yr ?

Maggi+ 2014

• Now more than 60 SNRs and still counting

• Multi-wavelengths studies → properties (density, abundance, age, ...)

• The faint end of the population

• Probe a variety of ISM environment
New SNRs in the LMC

Collection of new SNRs

Maggi+ 2014

- Now more than 60 SNRs and still counting
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New SNRs in the LMC

Highlights: Old type Ia remnants

Iron-rich gas in the interior

- $kT$ is 0.6 keV – 0.8 keV
- Long ionisation age ($\tau = n_e t$)
- $M_{Fe}$ is 0.5 $M_\odot$ to 1.2 $M_\odot$ for J0508-6830 and J0511-6759
- $M_{Fe}$ is 0.5 – 1.8 $M_\odot$ (J0508-6902)

Could NOT be observed in the Galaxy
New SNRs in the LMC

Highlights: Old type Ia remnants

The Evolution of the type Ia SNRs

Borkowski et al. 2006

<table>
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<tr>
<th>SNR</th>
<th>Age</th>
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<tr>
<td>DEM L238</td>
<td>~13500 yr</td>
</tr>
<tr>
<td>DEM L249</td>
<td>~ 15000 yr?</td>
</tr>
<tr>
<td>MCSNR J0508-6902</td>
<td>~23000 yr</td>
</tr>
<tr>
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MCSNR J0508-6902

MCSNR J0511-6759

MCSNR J0508-6830

Pierre Maggi (MPE)

SNR population of the LMC

16 June 2014
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<tr>
<td>SNR B0509-67.5</td>
<td>400 yr</td>
<td>SNR B0519-690</td>
<td>600 yr</td>
<td>N103B</td>
<td>~800 yr</td>
<td>DEM L71</td>
<td>~4400 yr</td>
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<tr>
<td>SNR B0548-704</td>
<td>~7100 yr</td>
<td>SNR B0534-699</td>
<td>~10100 yr</td>
<td>DEM L238</td>
<td>~13500 yr</td>
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**COMPLETE SPECTRAL (RE-)ANALYSIS**

- Homogeneous: allows comparison of properties ($kT$, ionisation age, abundances)
- Derive accurate flux; better than simple count rate conversion

→ Production of the most complete, homogeneous, accurate catalogue of the X-ray properties of LMC SNRs

Combine with information on:
- type of SN origin, if known
- local Star Formation History
Preliminary results: “SFH-typing”

Star Formation History in the neighbourhood of type Ia SNRs

Star formation rate vs. cosmic time (from the LMC SFH maps of Harris & Zaritsky 2009)
Preliminary results: “SFH-typing” (2)

Idem, for the population of core-collapse SNRs
Preliminary results: “SFH-typing” (2)

Idem, for the population of core-collapse SNRs

⇒ Distinguish likely type Ia and Core-Collapse SNRs, based on relative stellar masses formed “recently” and “long time ago”
• The population of definitive and likely type Ia SNRs dominates the faint end.
• At same temperature, type Ia SNRs tend to have lower luminosities.
⇒ Likely an effect of the low density media where type Ia SD explode, compared to the denser star-forming region hosting core-collapse SNRs.
On the spatial distribution of LMC SNRs

"O Remnants, where art thou ?"

Neutral Hydrogen

H I map from Kim et al. (2003)

Stars and Ionised gas

MCELS emission-line images
“O Remnants, where art thou?”

SNRs and X-ray-derived \( N_H \)

- ’stellar” bar in front

Tentative SN Type

- Star-forming regions visible
• The LMC is an **ideal laboratory** for the study of supernova remnants.

• XMM-Newton Large Programme survey found **new, fainter SNRs**, and revealed hidden details of those previously known.
  - They exemplify the impact of the host galaxy/environment on late-time morphological evolution of SNRs.
  - Three are iron-rich (type Ia) remnants $\mapsto$ the oldest known.

• A **complete** sample allows the study of the
  - **spatial distribution** of remnants in the LMC (w/ respect to the various local stellar populations),
  - **X-ray luminosity function** (even the faint end)

with unprecedented quality (compared to M31, M33, MW).
Keep observing the Clouds!

A view of the night sky over La Silla Observatory, Chile