SWXCS :
- Swift X-ray Cluster Survey

Teng Liu, July 2\textsuperscript{nd}, 2013

Outline

- EXSdetect: a new software
- Simulation to evaluate SWXCS
- SWXCS catalogs

The Swift X-ray Cluster Survey (SXCS) is an ongoing project aimed at finding serendipitously galaxy clusters in the Swift X-ray Telescope (XRT) archive.
The first step of X-ray cluster survey
Extended X-ray source detection

- Difficulties of detecting faint X-ray sources
  - Low count
  - Sparse background
  - Low resolution

- Much worse for extended sources
  - More spread, lower contrast
  - Hard to distinguish between extended and unresolved sources with low S/N

- There are only a few general-purpose source detection tool

→ a software optimized for extended sources?
VT+FoF: potentially better for extended source

Voronoi tessellation + Friend-of-friend

- Sensitive to faint diffuse emission
- Full angular resolution preserved
- Morphology investigator

“Vtpdetect” Ebeling et al. 1993 but never brought into full-play

→ a new software “EXSdetect”
Solving the problems of VT+FoF

- Using the **fastest algorithm** to do VT
- De-blending automatically

From wikipedia
Classification & photometry

- Extended or unresolved
  - Sort the pixels inside a fixed circle
  - Compare with PSF model by KS test
- Photometry
  - within the FoF detected regions
Highlights of EXSdetect

- A modern implementation of VT+FoF
- Solving the blending problem automatically (important for low resolution instrument like eROSITA)
- The first end-to-end software, not only a source detection tool
  Detection + Classification + Photometry
- Open-source and flexible, can be used or further developed by the whole community
Simulating SWXCS

- Both to test “EXSdetect” and to evaluate SWXCS catalogs

- For each field of SWXCS
  - Using the real
    - Exposure map
    - Energy conversion factor
    - PSF of Swift-XRT
    - Background level

Real image

Mock image
Simulating SWXCS

AGN logN-logS from CDFS
Cluster logN-logS from ROSAT survey

Templates: a few Chandra observed clusters with very different radial brightness profiles
Simulation result

Above 80 net counts

- >80% completeness
- Acceptable contamination

Source classification and de-blending are the bottlenecks

→ spatial resolution is essential

eROSITA 25”-30”
WFXT 5”
Simulation result
Unbiased photometry
Now back to real data

- ~300 GRB follow-up fields $\rightarrow$ ~4000 extra-galactic fields
- 100 count lower limit $\rightarrow$ >80 count using “EXSdetect”

Tundo et al. 2012  
Liu et al. in preparation
SWXCS Catalog I

- Catalog I
- 72 clusters, mostly new
  (Tundo et al. 2012)
- 46 with $z$, $T$, $L$
  (Tozzi et al. in preparation)

Tozzi et al. in preparation

Tundo et al. 2012
Multi-band observations

- Cross-correlation with X-ray and optical catalogs
  20/72 already confirmed clusters (Tundo et al. 2012)

- **Comparison with Chandra observation**
  spectra analysis of SWXCS J123620.1+285905
  Good agreement between XRT and Chandra

- **Optical follow-up**
  Will be presented by Elena Tundo tomorrow afternoon
Final catalog
(Liu et al. in preparation)

- **Swift-XRT archive 2012**
- **80 count lower limit with well controlled selection function due to our simulation**
- ~300 clusters
- ~100 with z, T, L measurements
- Future work
  - cross-correlate with optical, SZ catalogs
  - basic cosmological tests

From which the Vikhlinin09 high-z sample was selected

Well controlled survey volume
SWXCS vs other X-ray Cluster surveys

Swift-XRT: a new instrument for cluster survey other than XMM and Chandra

<table>
<thead>
<tr>
<th>Name</th>
<th>Flux limit</th>
<th>solid angle</th>
<th>Number of sources</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEXCLAS</td>
<td>$0.6 \times 10^{-14}$ (min)</td>
<td>2.1</td>
<td>19</td>
<td>Kolokotronis et al. (2006)</td>
</tr>
<tr>
<td>DCS</td>
<td>$0.6 \times 10^{-14}$ (min)</td>
<td>5.55</td>
<td>36</td>
<td>Boschin (2002)</td>
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<tr>
<td>ChaMP</td>
<td>$1.0 \times 10^{-14}$ (min)</td>
<td>13.0</td>
<td>49</td>
<td>Rostovtsev et al. (2006)</td>
</tr>
<tr>
<td><strong>SXCS</strong></td>
<td>$1.0 \times 10^{-14}$ (min)</td>
<td><strong>40.0</strong></td>
<td><strong>72</strong></td>
<td>Tundo et al. 2012</td>
</tr>
<tr>
<td>XDCP</td>
<td>$1.0 \times 10^{-14}$ (average)</td>
<td>76.0</td>
<td>22 ($z &gt; 0.9$)</td>
<td>Fassbender et al. (2011)</td>
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<td>XCLASS</td>
<td>$2 \times 10^{-14}$ (min)</td>
<td>90.0</td>
<td>347</td>
<td>Clerc et al. (2012)</td>
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<td>Peterson09</td>
<td>$\sim 0.3 \times 10^{-14}$ (min)</td>
<td>163.4</td>
<td>462</td>
<td>Peterson et al. (2009)</td>
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<tr>
<td>XCS</td>
<td>$&gt; 300$ net cts</td>
<td>410.0</td>
<td>993</td>
<td>Lloyd-Davies et al. (2011)</td>
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<tr>
<td>SXDF</td>
<td>$0.2 \times 10^{-14}$ (min)</td>
<td>1.3</td>
<td>57</td>
<td>Finoguenov et al. (2010)</td>
</tr>
<tr>
<td>COSMOS</td>
<td>$0.2 \times 10^{-14}$ (min)</td>
<td>2.1</td>
<td>72</td>
<td>Finoguenov et al. (2007)</td>
</tr>
<tr>
<td>XMM-BCS</td>
<td>$0.6 \times 10^{-14}$ (min)</td>
<td>6.0</td>
<td>46</td>
<td>Suhada et al. (2012)</td>
</tr>
<tr>
<td>XMM-LSS</td>
<td>$\sim 10^{-14}$ (min)</td>
<td>11.0</td>
<td>66</td>
<td>Adami et al. (2011)</td>
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</tbody>
</table>
Summary of SWXCS

- An independent survey other than using XMM and Chandra, getting comparable depth and area to current surveys.
- A large complete flux-limited sample with well defined selection function.
- A subsample well characterized with only X-ray data, and can be used in cosmological tests.
What else we learn from SWXCS

- Swift-XRT: small but efficient in cluster survey
- Benefit from the design of
  - Constant PSF
  - Low background
- Imagine a next generation telescope with the above characteristics after eROSITA -- WFXT, which will provide a survey similar to SDSS in X-ray band.

Thanks
EXSdetect as not-only a part of SWXCS

- To construct the SWXCS catalog, and have full-control of its characteristics
- Meaningful to exploit the large amount of X-ray archive of XMM, Chandra with a new method
- Much larger amounts of data is coming from future all-sky survey, eROSITA and maybe WFXT
Cluster survey in X-ray band

- Advantages in X-ray band
  - Single extended source in sparse field
  - X-ray emissivity $\propto n_e^2$, different
  - Well controlled selection function
  - Efficient mass estimation

- Important even considering the exciting progress of SZ observation
  - Firmly evaluate sample completeness and purity
  - Improve mass estimation

[powerful tool for cosmological tests]
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