Demographics of X-ray and Mid-Infrared Selected AGN from the Wide-Area Stripe 82X Survey

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Towards a comprehensive census of AGN

Unobscured

Obscured

animation idea credit: R. Pfeifle
Importance of Obscured AGN

• Majority of local AGN population e.g., Comastri 2004, Treister+ 2004

• Can be transitional link in merger-induced SMBH/galaxy co-evolution paradigm e.g., Sanders+ 1988, Hopkins+ 2008

• Mitigate optical bias with X-ray & MIR selection
Importance of Wide Area Surveys

• Only way to discover rare objects, e.g. high-L & high-z AGN
• Rare but important
  – Signal when majority of mass accreted on SMBHs occurs Hopkins & Hernquist 2009, Treister+ 2012
  – Key players in galaxy evolution Glikman+ 2012, 2013; Banerji+ 2013, 2015; Stern+ 2014; Assef+ 2015
• Already wide area surveys in
  – optical (e.g., SDSS ~35% of sky)
  – IR (e.g., WISE – all sky)

X-rays starting to catch up
Stripe 82 X-ray Survey (Stripe 82 X)
What is Stripe 82?
SDSS Coverage up to Data Release 7 (July 2008)
SDSS Stripe 82 Legacy Field

• 300 deg² along celestial equator
  - -60 < RA < 60
  - -1.25 < Dec < 1.25

• Deep photometry (~2 mag deeper than rest of SDSS)

• High level of spectroscopic completeness
  – SDSS, 2SLAQ, WiggleZ, DEEP2, PRIMUS, HETDEX

• Tons of λλλ coverage
Power of $\lambda \lambda \lambda$ coverage
Power of $\lambda\lambda\lambda$ coverage
Power of $\lambda\lambda\lambda$ coverage

![Graph showing power of $\lambda\lambda\lambda$ coverage with UKIDSS and VHS data points.](image-url)
Power of $\lambda\lambda\lambda$ coverage

![Graph showing power of $\lambda\lambda\lambda$ coverage with WISE and Spitzer data points.](image)
Power of $\lambda\lambda\lambda$ coverage

\[ \nu F_\nu \left(10^{-13} \text{ erg s}^{-1} \text{ cm}^{-2} \right) \]

\[ \text{Wavelength (Å)} \]

FIR

\textit{Herschel}
Stripe 82 X-ray Data From

XMM-Newton

Chandra
Stripe 82 X-ray Coverage
Stripe 82 X-ray Coverage

Archival Chandra
LaMassa+ 13b

Archival XMM
LaMassa+ 13c

Chandra + Archival XMM

Area (deg²)

$F_{0.5-2\text{keV}}$ (erg s⁻¹ cm⁻²)
Stripe 82 X-ray Coverage

- Archival *Chandra*
  LaMassa+ 13b

- Archival *XMM*
  LaMassa+ 13c

- *XMM* AO10
  LaMassa+ 13c
Stripe 82 X-ray Coverage

**Archival Chandra**
LaMassa+ 13b

**Archival XMM**
LaMassa+ 13c

**XMM AO10**
LaMassa+ 13c

**XMM AO13**
LaMassa+ 16a

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**S82X Total**

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**$F_{0.5-2keV}$ (erg s$^{-1}$ cm$^{-2}$)**

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**Area (deg$^{-2}$)**
## Stripe 82 X-ray Survey Summary

<table>
<thead>
<tr>
<th>Survey</th>
<th># of Sources</th>
<th>Area (deg²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archival <em>Chandra</em></td>
<td>1146</td>
<td>7.4</td>
</tr>
<tr>
<td>Archival <em>XMM</em></td>
<td>1607</td>
<td>6.0</td>
</tr>
<tr>
<td><em>XMM AO10</em></td>
<td>751</td>
<td>4.6</td>
</tr>
<tr>
<td><em>XMM AO13</em></td>
<td>2862</td>
<td>15.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6181</strong></td>
<td><strong>31.3</strong></td>
</tr>
</tbody>
</table>

LaMassa+ 2016a

cf Chandra COSMOS Legacy (2.2 deg²): 4016 Civano+ 2016
Chandra Deep Field South (0.13 deg²): 1009 Luo+ 2017
Counterparts to S82X Sources via Maximum Likelihood Estimator: 6059

<table>
<thead>
<tr>
<th>Survey</th>
<th>Number</th>
</tr>
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<tbody>
<tr>
<td>Optical</td>
<td>5575</td>
</tr>
<tr>
<td>MIR $\textit{(Spitzer)}$</td>
<td>4575</td>
</tr>
<tr>
<td>MIR $\textit{(WISE)}$</td>
<td>3550</td>
</tr>
<tr>
<td>NIR $\textit{(UKIDSS)}$</td>
<td>3623</td>
</tr>
<tr>
<td>NIR $\textit{(VHS)}$</td>
<td>4612</td>
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<tr>
<td>FIR $\textit{(Herschel)}$</td>
<td>133</td>
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<tr>
<td>UV $\textit{(GALEX)}$</td>
<td>1243</td>
</tr>
<tr>
<td>Radio $\textit{(FIRST)}$</td>
<td>232</td>
</tr>
<tr>
<td>Redshifts</td>
<td>2224</td>
</tr>
</tbody>
</table>

Ananna+ 2017, LaMassa+2016a,2019
Stripe 82 X-ray Coverage

Archival *Chandra*
LaMassa+ 13b

Archival *XMM*
LaMassa+ 13c

*XMM* AO10
LaMassa+ 13c

*XMM* AO13
LaMassa+ 16a

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S82X Total

XMM AO13

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Area (deg$^2$)

$F_{0.5-2\text{keV}}$ (erg s$^{-1}$ cm$^{-2}$)
SDSS IV eBOSS Stripe 82X Spectroscopic Survey

XMM AO13 survey area: 15.6 deg$^2$

SDSS spectroscopic plates: 36.8 deg$^2$
**WISE W1-W2 AGN Selection**

Assef+ 2013, 2018 75% reliability criterion

Largest spectroscopic survey of W1-W2 selected AGN
SDSS IV eBOSS Stripe 82X Results

- 4847 X-ray sources & WISE AGN candidates w/ spectra
  - 82% complete to $r \sim 22$
  - 4730 AGN
    - 1790 X-ray AGN ($L_x > 10^{42}$ erg/s)
    - 3638 WISE AGN (recall larger targeting area for WISE)
    - 698 both X-ray & WISE

LaMassa et al. 2019
Demographics of X-ray & MIR-Selected AGN in Stripe 82X

LaMassa+ 2019
**SDSS IV eBOSS Stripe 82X Results**

**Full spectroscopic sample:**

<table>
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<th>Classification</th>
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<th>WISE AGN</th>
<th>Both</th>
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<tr>
<td>Type 1 AGN</td>
<td>1427</td>
<td>2529</td>
<td>646</td>
</tr>
<tr>
<td>Optically Obscured AGN</td>
<td>362</td>
<td>1108</td>
<td>52</td>
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Just from eBOSS program:

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<td>335</td>
<td>354</td>
<td>85</td>
</tr>
<tr>
<td>Optically Obscured AGN</td>
<td>269</td>
<td>844</td>
<td>40</td>
</tr>
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</table>

76% of obscured AGN from targeting these sources

LaMassa et al. 2019
About that MIR “obscured AGN” fraction…

50% are in star-forming galaxy locus

Star-forming galaxies masquerading as AGN or deeply buried AGN? see Satyapal+ 2018, Georgakakis+ in prep.

LaMassa et al. 2019
Comparison of X-ray & WISE AGN

Restricted to *XMM* AO13 footprint
Demographic Summary of X-ray & WISE AGN

2751 AGN total: 29% obscured fraction

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Demographic Summary of X-ray & WISE AGN

25% X-ray & WISE AGN
Demographic Summary of X-ray & WISE AGN

- 39.5% X-ray only; 61% X-ray AGN not WISE AGN
- 25% X-ray & WISE
- 35.5% WISE only; 58% WISE AGN not X-ray AGN
X-ray AGN

LaMassa et al. 2019
X-ray & WISE AGN

LaMassa et al. 2019
X-ray AGN: WISE detections, blue MIR colors

See also: Eckert+ 2010, Mendez+ 2013, Menzel+ 2016, LaMassa+ 2016b
X-ray AGN: **not** detected by WISE

“Hot Dust Poor Quasars”? Hao+ 2010, 2011, Lyu+ 2017

LaMassa et al. 2019
WISE AGN

LaMassa et al. 2019
WISE AGN: X-ray detected

LaMassa et al. 2019
WISE AGN: not X-ray detected

not predominantly redder/more obscured...
Stripe 82X Highlights

- 31 deg², 6181 X-ray sources *LaMassa+ 2013b,c,2016*
  - See *LaMassa+ 2016, Ananna+ 2017* for X-ray/λλλ catalogs
- Demographics lessons f/ 15.5 deg² XMM-AO13 area *LaMassa+ 2019:*
  - *observed* obscured AGN fraction 20 – 30% to r ~22
    - significant star-forming galaxy contamination at low z for *WISE* AGN? *Georgakakis+ in prep*
  - 61% of X-ray AGN *not* MIR-selected AGN
    - 39% have blue *W1-W2* colors: Low L *Eckert+ 2010, Mendez+ 2013, Menzel+ 2016, LaMassa+ 2016b*
    - 22% *undetected* by *WISE*: High L *Hao+ 2010, 2011*
  - 58% of *WISE* AGN are *not* X-ray detected
    - no trend in *W1-W2* color: not more obscured?
Backup