Max-Planck-Institut für
extraterrestrische Physik

X-RAY SELECTED AGN BEHIND THE MAGELLANIC CLOUDS

Chandreyee Maitra

Frank Haberl (MPE), Valentin V. Ivanov & Maria-Rosa L. Cioni (VMC survey)

Treasures Hidden in High Energy Catalogues
IRAP, Toulouse
24th May, 2018

Outline

- Finding AGNs behind the Magellanic clouds is important
- The current census in X-rays: XMM-Newton survey of the Magellanic clouds
- Characterisation of the sample (SMC, LMC: preliminary!)
- Future prospects

Finding AGNs behind the Magellanic Clouds

- Identifying AGNs behind the Magellanic clouds (MCs) is difficult because of the high stellar density in these fields

- ~Only 80 quasars discovered behind the MC up to 2009 (Dobrzycki et al. 2005 & references within)

- Many AGNs were found with the Magellanic Quasar Survey (MQS) (Kozlowski & Kochanek 2009; Kozlowski et al. 2011; 2013).

- Targets were selected from OGLE -III based on their mid IR colors, optical variability and a small sample (~10%) X-ray selected sources from ROSAT survey. Spectroscopically confirmed 758 (565 LMC and 193 SMC) Quasars

- XMM-Newton survey of the SMC (Haberl et al. 2012) was used for association of X-ray point sources with radio emission to select AGNs (Sturm et al. 2013)

- **1.4 million AGN from AllWISE mid-IR survey (Secrest et al. 2015), Half Million Quasars, MILLIQUAS (Flesch+15,+17)**

- **VISTA Magellanic Cloud Survey (Cioni et al. 2013, Ivanov et al. 2016)**

BULK of sources identified in the MCs expected to be AGNs in X-rays: > 71% in SMC (Sturm et al. 2013)

Valuable sample of sources because..

- Interesting targets for investigations using multi-epoch and multi-wavelength data
- **Ideally suited for astrometric reference points, as needed to derive precise coordinates: important to improve the quality of X-ray catalogs of the MCs & proper-motion studies (Piatek et al. 2008; Cioni et al. 2014)**
- The brightest sources behind the densest regions can be used to probe absorption of interstellar medium in the MCs

Using X-ray and IR for sample selection

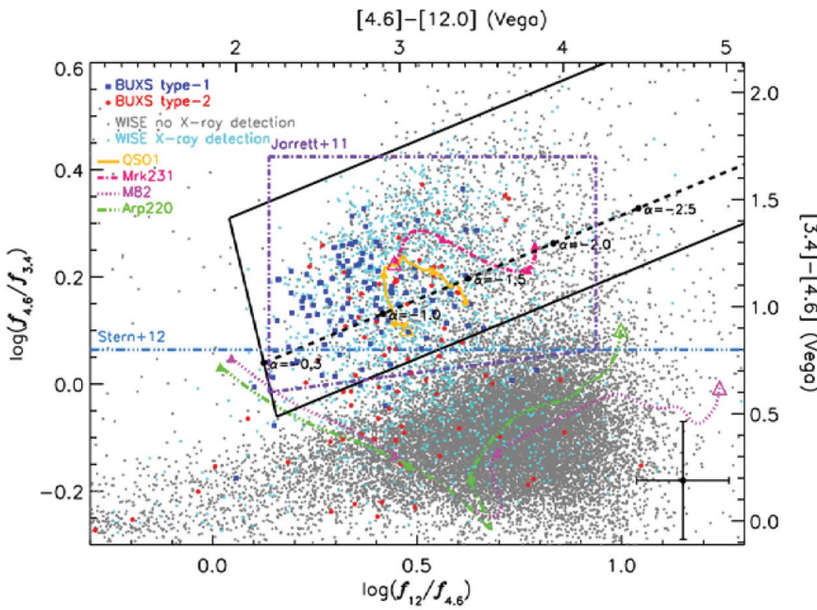
- AGNs separate cleanly from stars and other star forming galaxies in mid-IR color-space

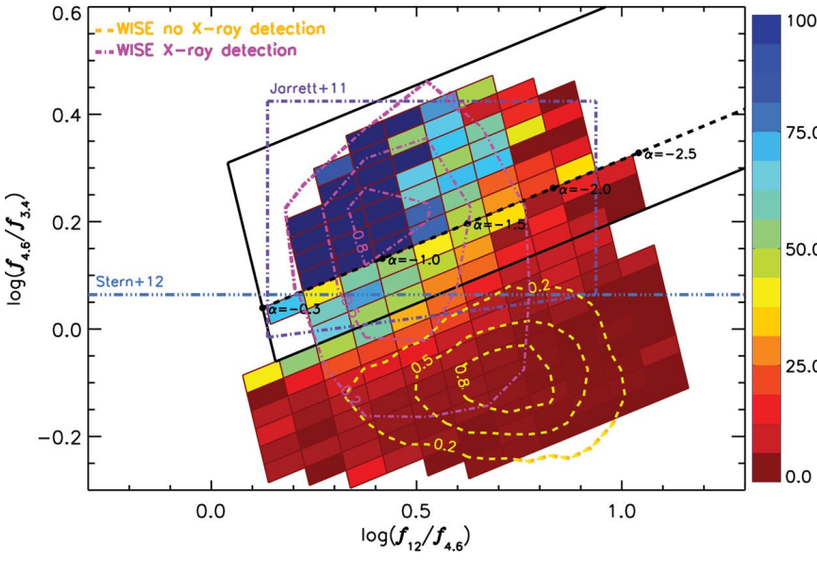
- Mid-IR is insensitive to extinction. Can pick out heavily obscured or even Compton-thick AGN.

- Hard X-rays (few keV ~10 keV) can also probe AGN activity & almost uncontaminated by star formation process; & sensitive to all but the most absorbed AGN ($N_H >= 10^{24}$ cm^{-2}) (Della Ceca et al. 2008)

- All sky sample of ~1.4 million AGN meeting a two-color mid-IR photometric selection criteria from ALLWISE (Secrest el al. 2015)

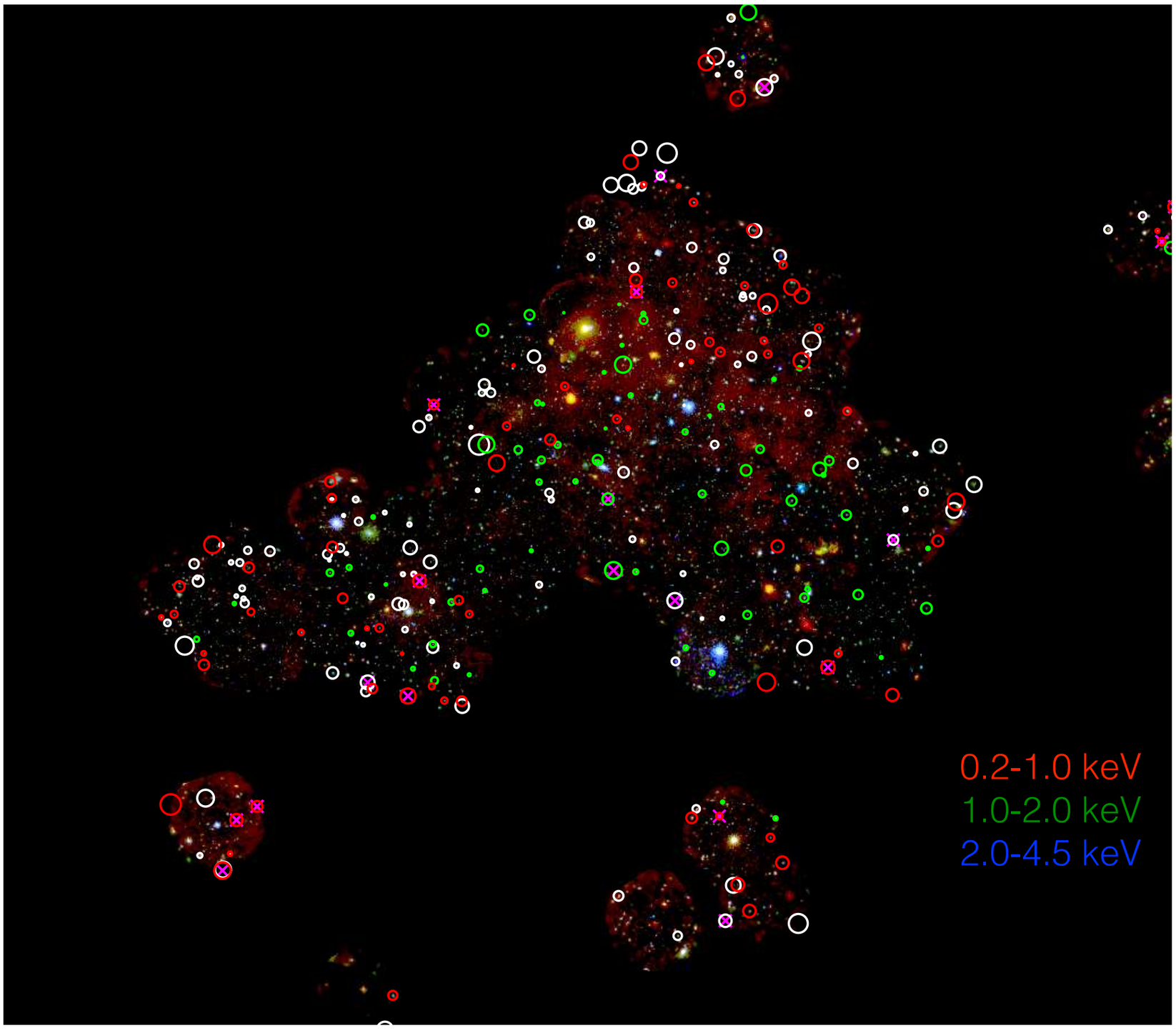
- Correlation of MIR data based on color selection (ALLWISE) with point sources from X-ray surveys (XMM-*Newton*) is an efficient way to trace out AGN





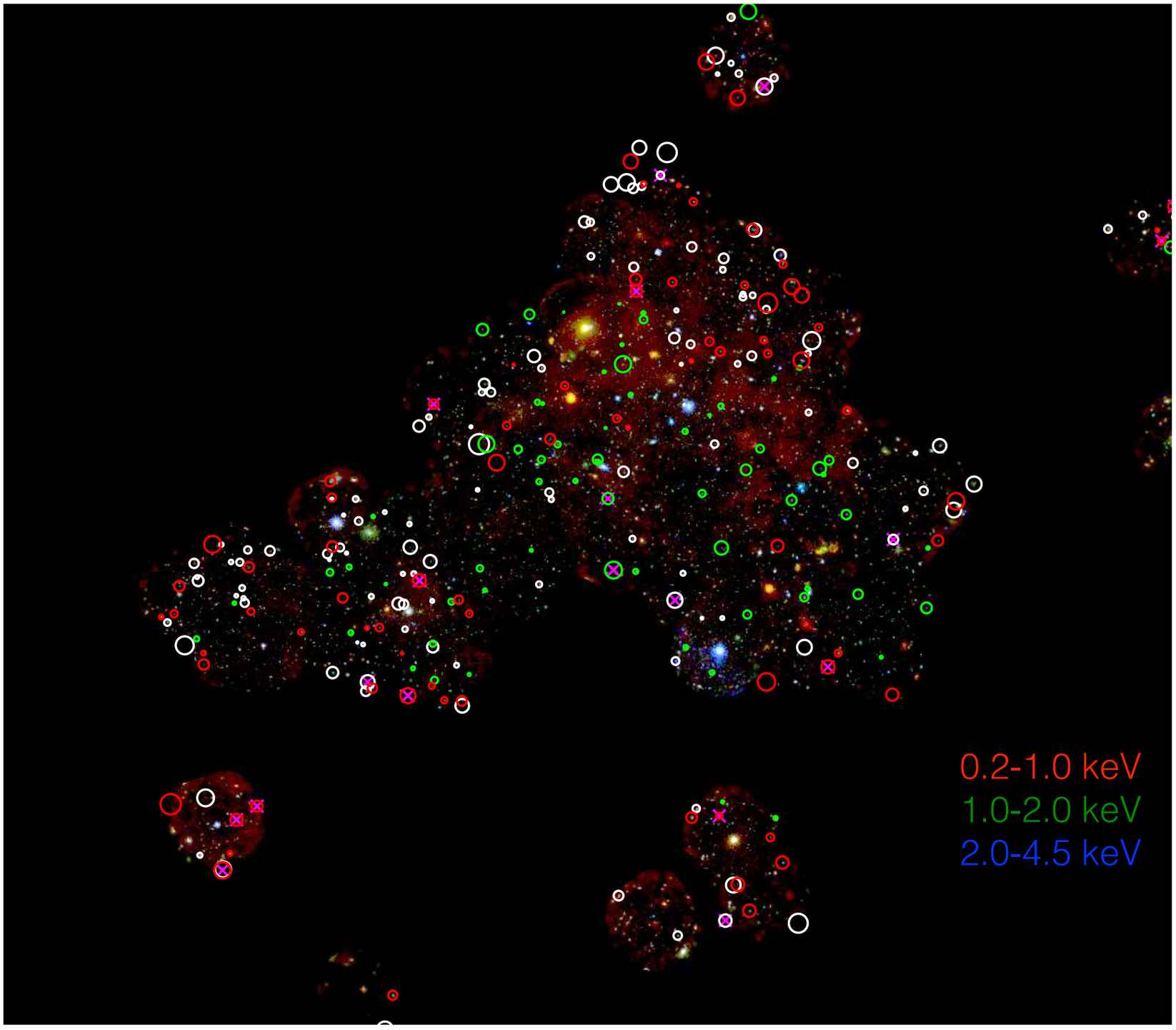
Mateos+12: Selected using BUXS

X-ray selected AGN behind the SMC



- SMC: ~6.67 $deg^{2;}$ 3.4 Ms
- 148 XMM-*Newton* pointing (~ 20 ks each pointing)
- 4449 unique sources with at leas one detection with detection likelihood ≧10
- 2753 sources (94% ALLWISE + HMQ/MILLIQUAS)
- Also selected ALLWISE sources with good-quality & S/N≧ 3 in ALLWISE

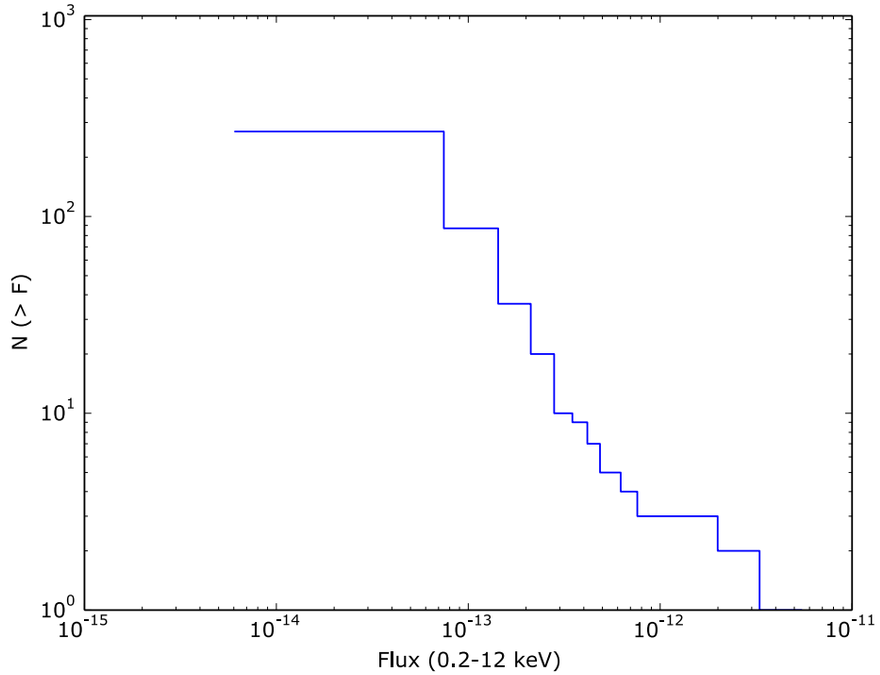
X-ray selected AGN behind the SMC



- 276 sources (probability of chance coincidence < 0.01)
- 81 new candidates (S/N ≧ 3 in ALLWISE)
- Used to perform astrometric corrections on pointings

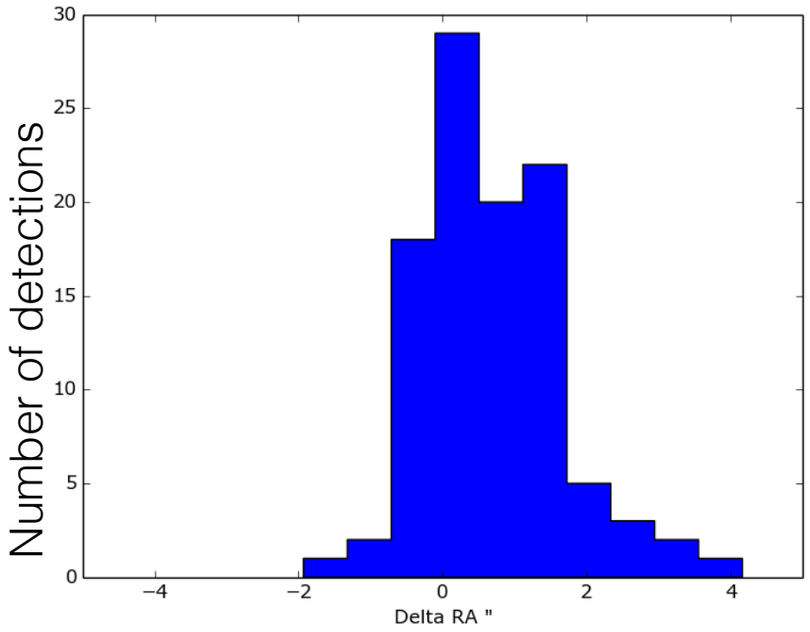
X-ray selected AGN behind the SMC

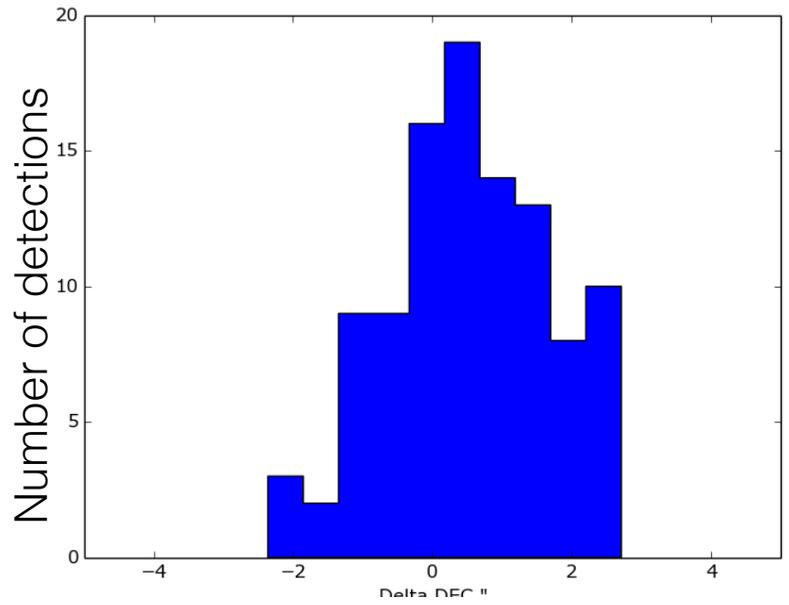
Reference	Number of sources	Comments
Secrest et al. (2015)	137	29 also included in HMQ/MILLIQUAS
HMQ/MILLIQUAS	58	None in ALLWISE
New candidates	81	catalogued as AGN candidates for the first time



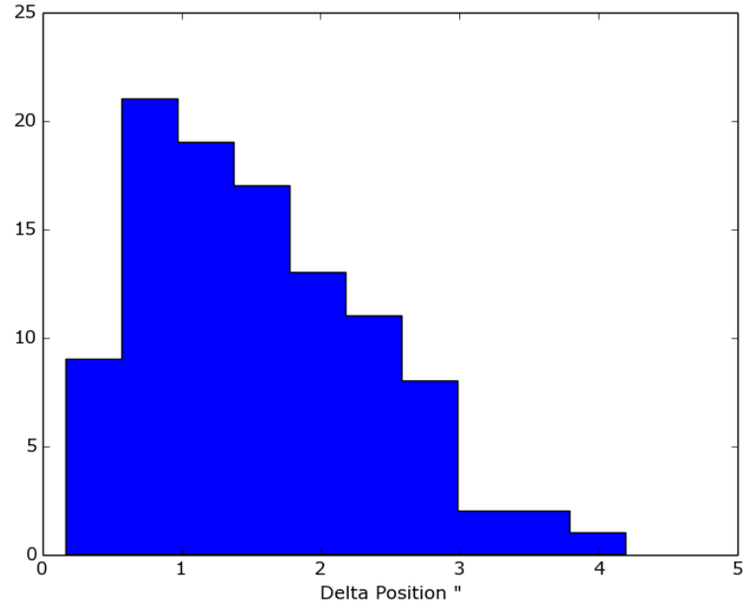
From XMM: Assuming homogenous distribution~ 41 AGNs/ sq. degree

Astrometric boresight corrections of the SMC fields

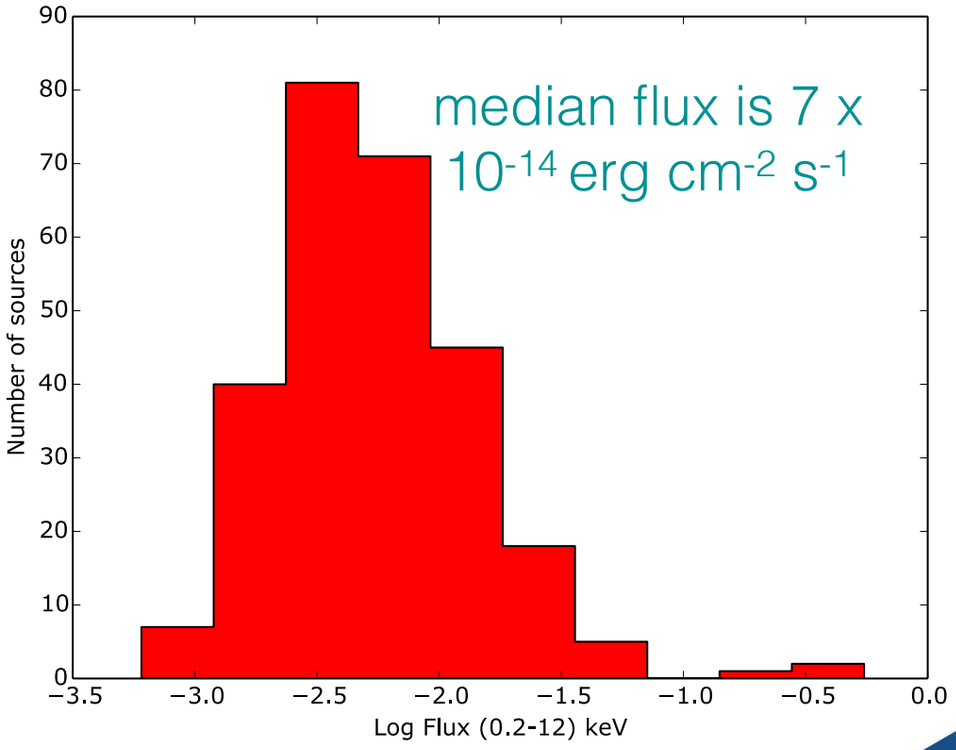


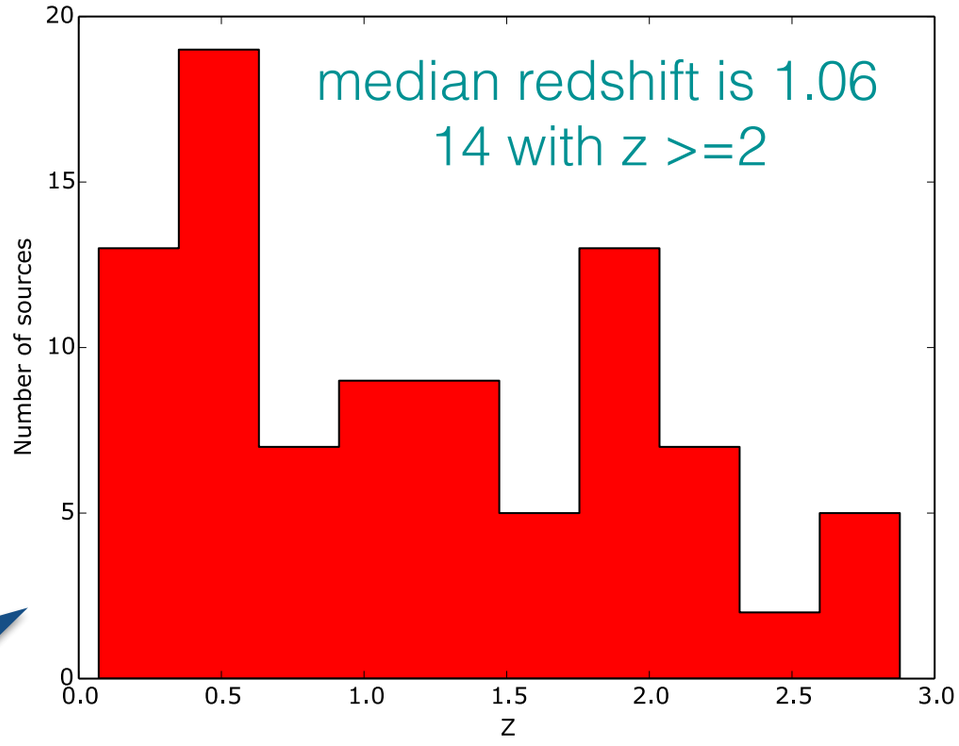


- Out of 148 XMM-*Newton* pointings, 9 could not be astrometrically corrected due to lack of reference sources; others >= 3 sources in the field

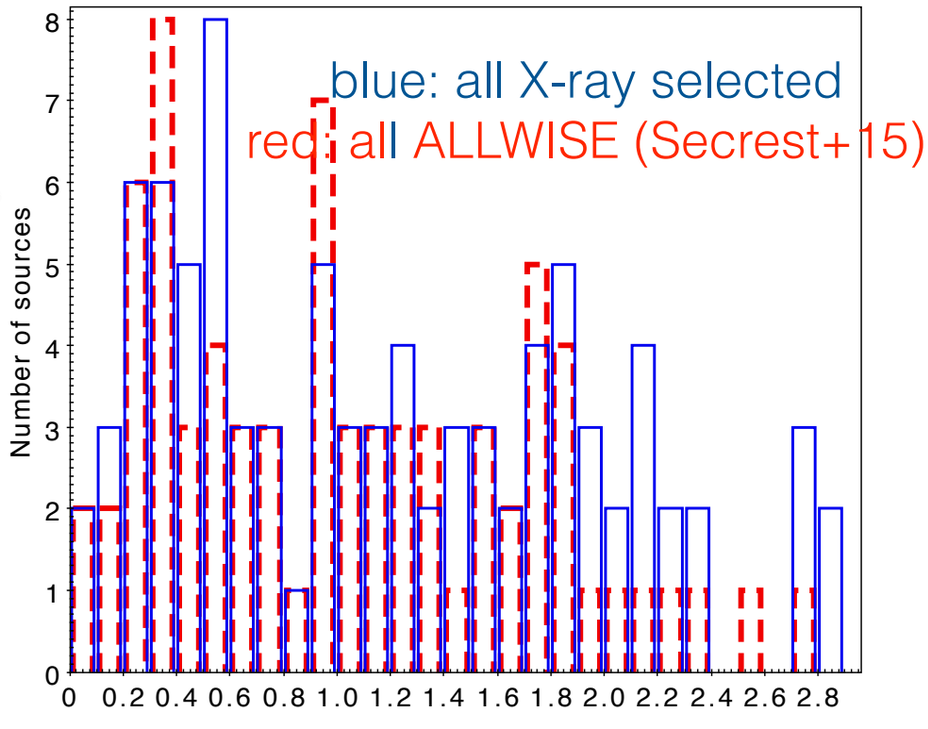


Flux and z distribution

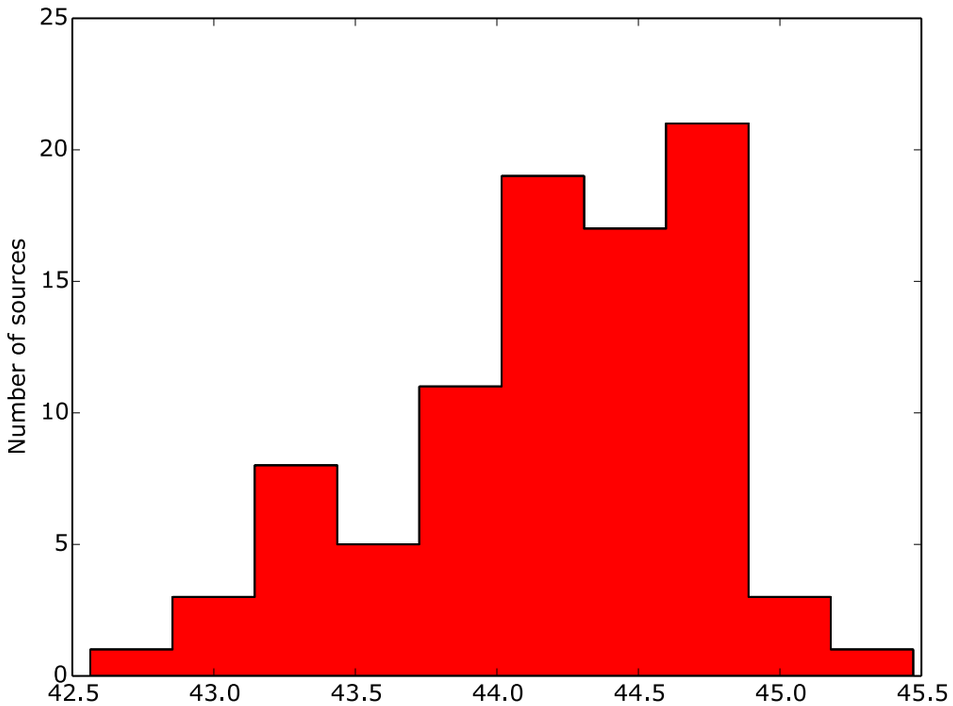


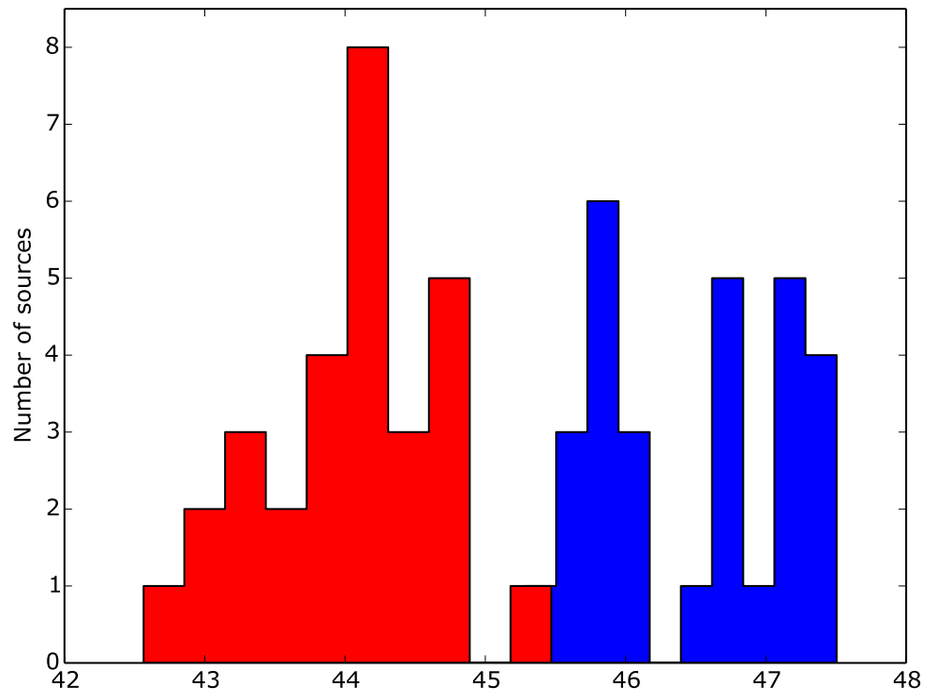


- z information from HMQ, MILLIQUAS, very few from ALLWISE (only 29 out of 90)



Luminosity distribution in X-rays and mid-IR

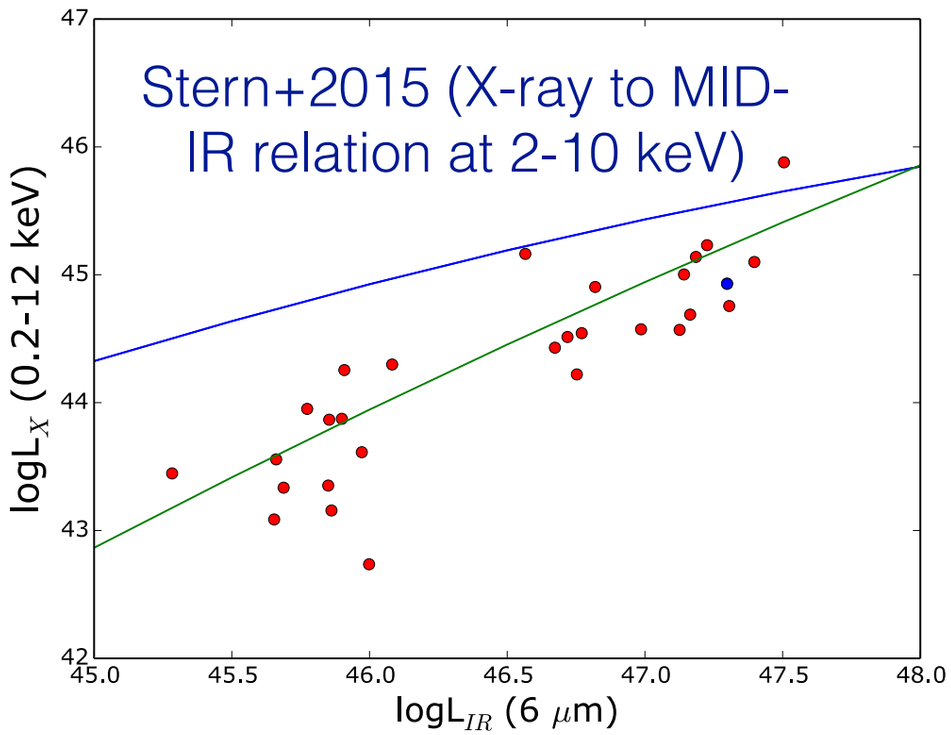




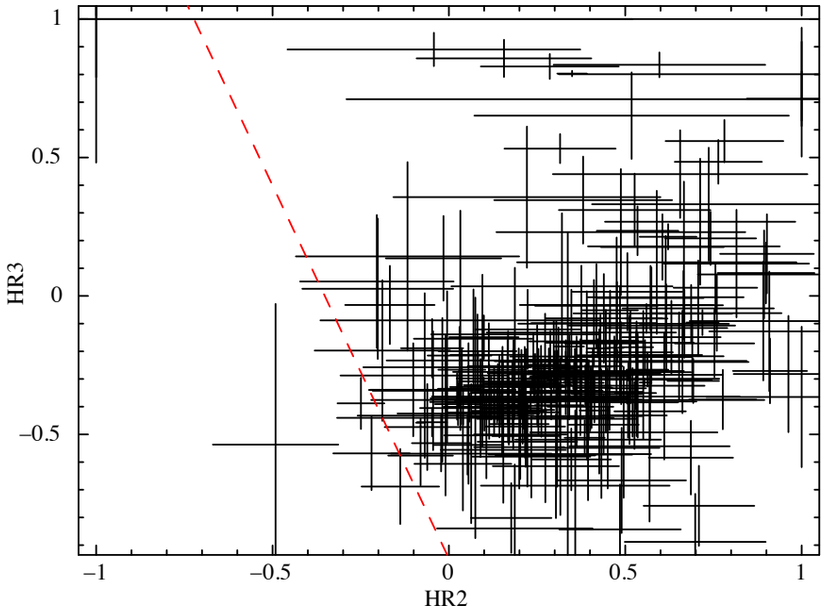
Red: 0.2-12 keV X-ray
Blue: (vLv) 6 um IR luminosity: unbiased estimate of true luminosity

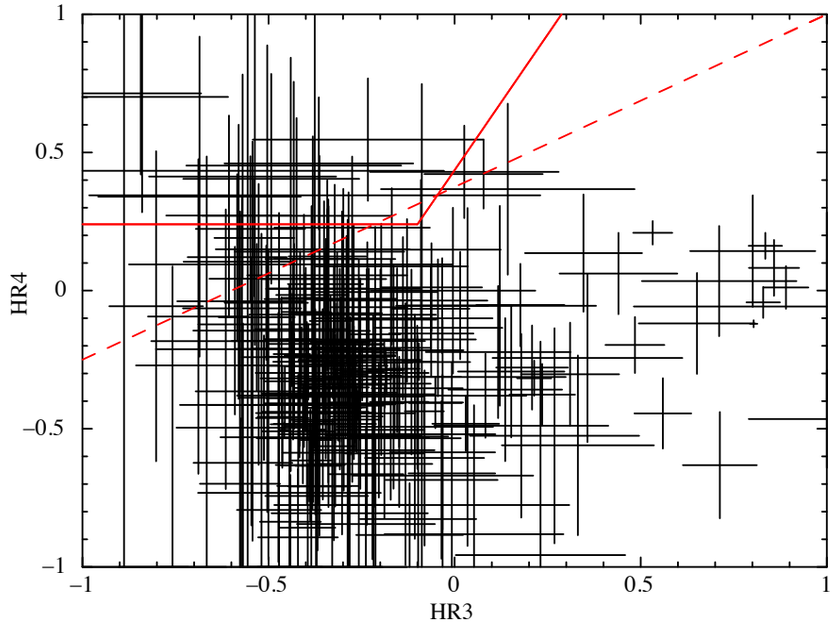
X-ray luminosities found systematically lower than predicted: presence of X-ray obscuration?

Addition obscuration of NH ~10^{21} & 10^{22} cm^{-2} decreases flux by 9% and 30% in the energy range of 0.2-12 keV



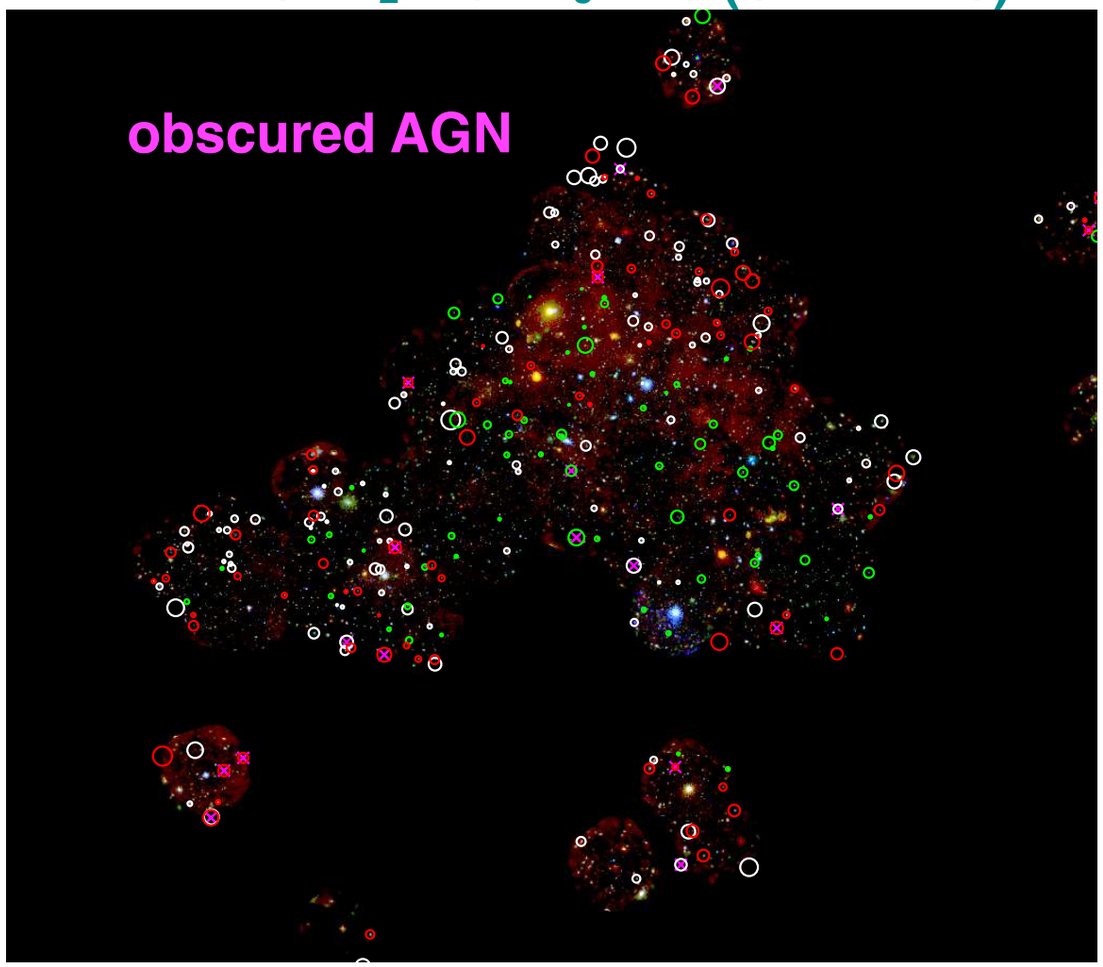
X-ray spectral characteristics





$HRi=(R_{i+1} - R_i)/(R_{i+1} + R_i)$

$8HR_2 + 3HR_3 > -3$ (Sturm+13)

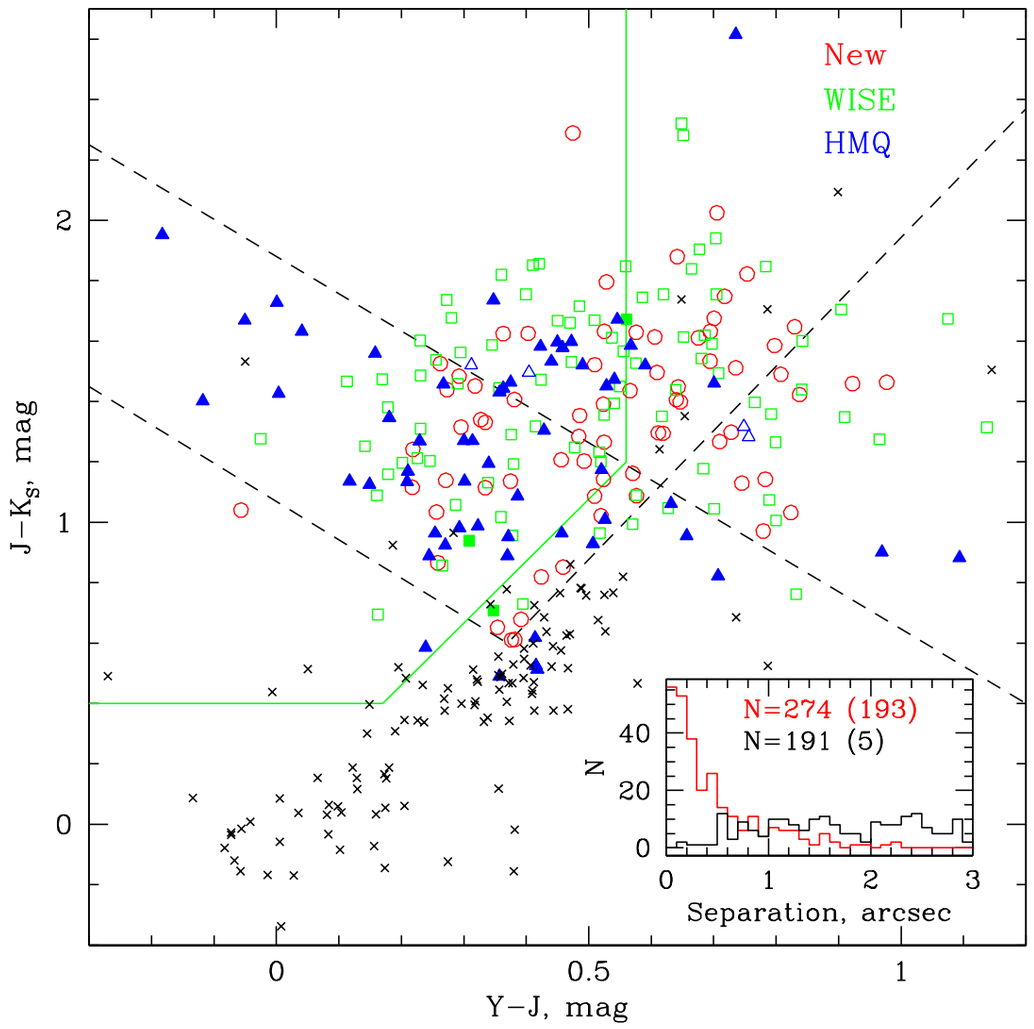


- **Brightman & Nandra+12 criterion for obscured AGNs:**
- **20** sources identified (**13** satisfy criterion for **Compton-Thick** AGNs, **1** z =2.18)

- Identification of obscured and distant quasars crucial to reproduce the shape of the CXB and understand AGN/galaxy co-evolution (Gilli+07, Lansuizi+14)
- Observed fraction is consistent with the XMM survey of the LOCKMAN hole & COSMOS field (Hasinger+01,07).

Near-IR VISTA (VMC) counterparts

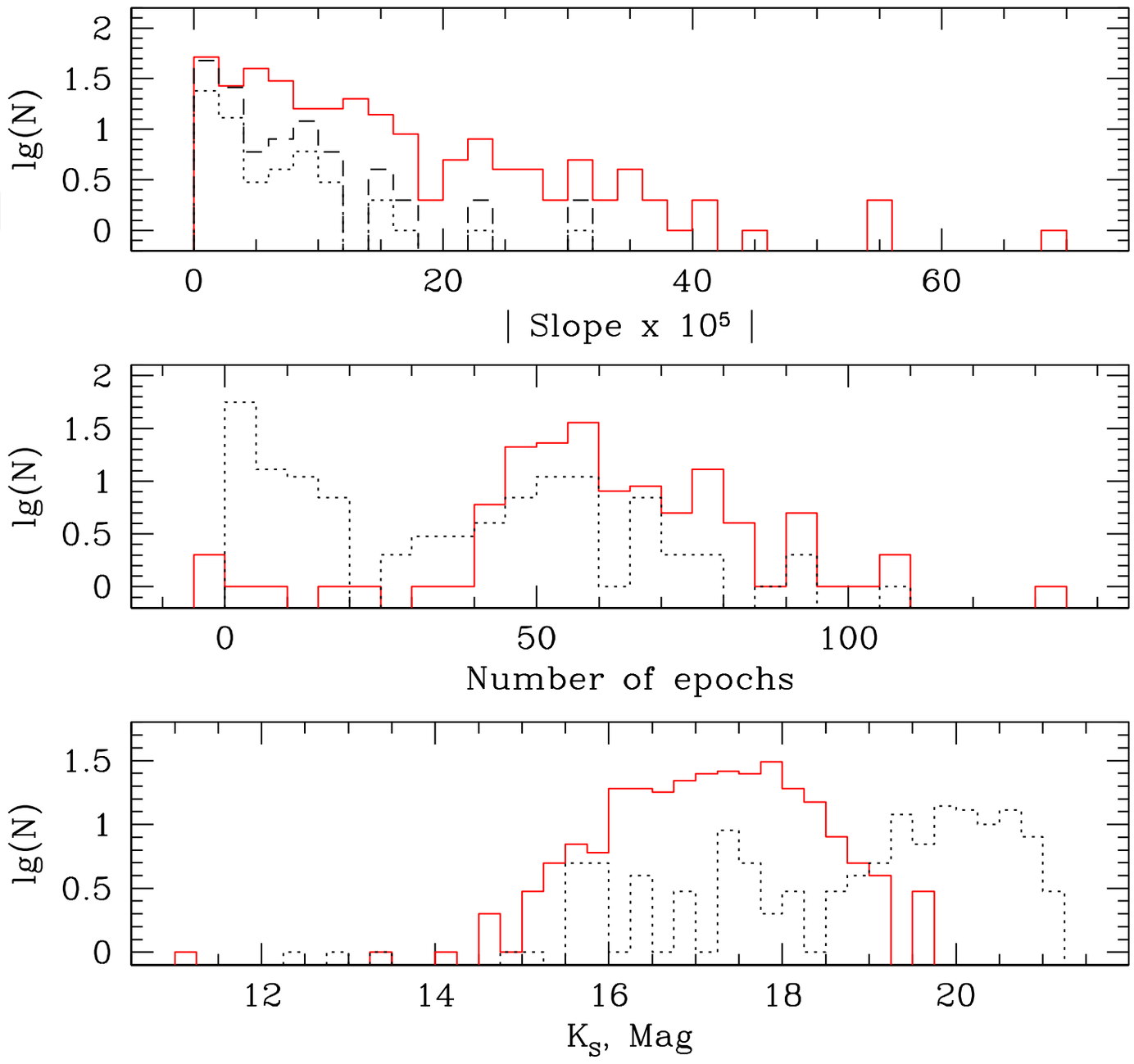
- Searched for the nearest VISTA counterpart for the ALLWISE/HMQ selected source
- 274 out of 276 sources have VISTA counterparts (secure identifications for angular separation < 0.5")



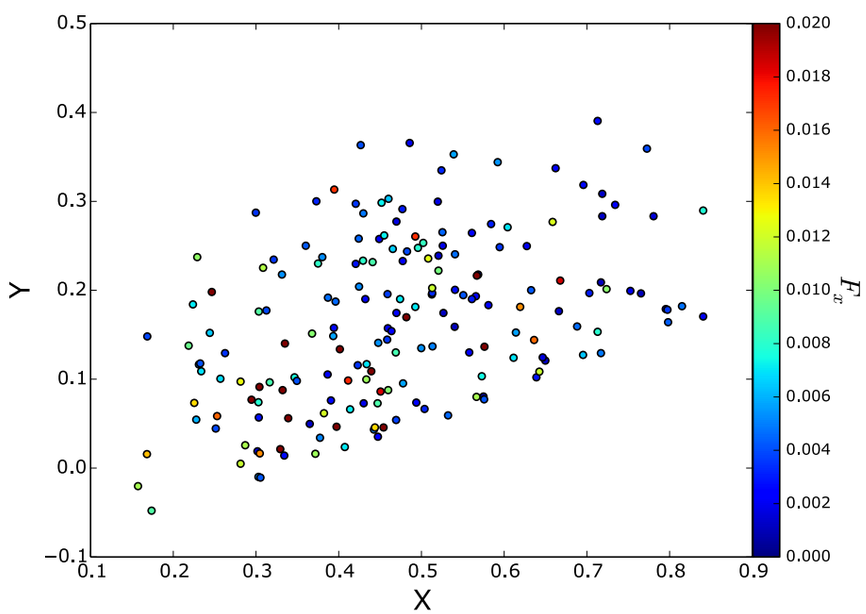
sources overlayed on VMC color-color diagram (Cioni+13)

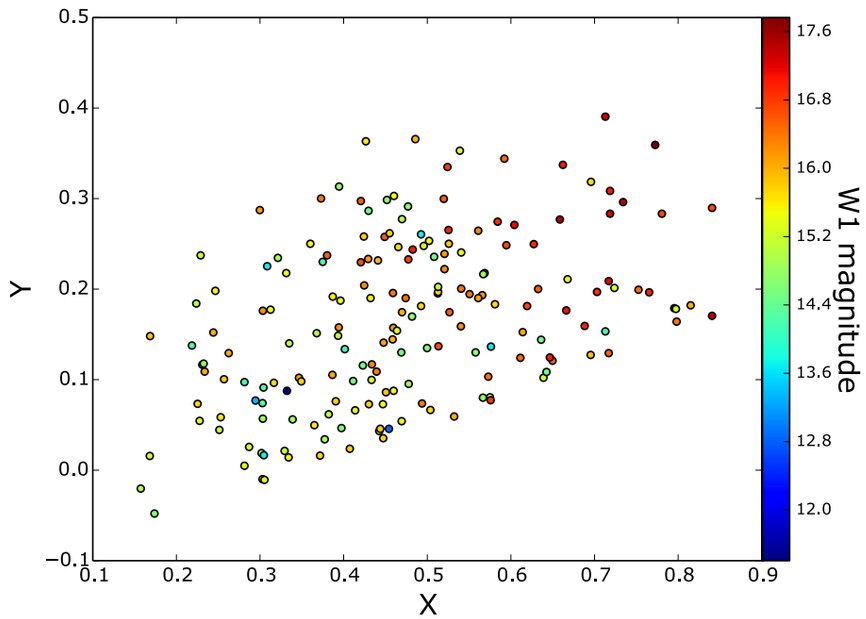
Near-IR variability

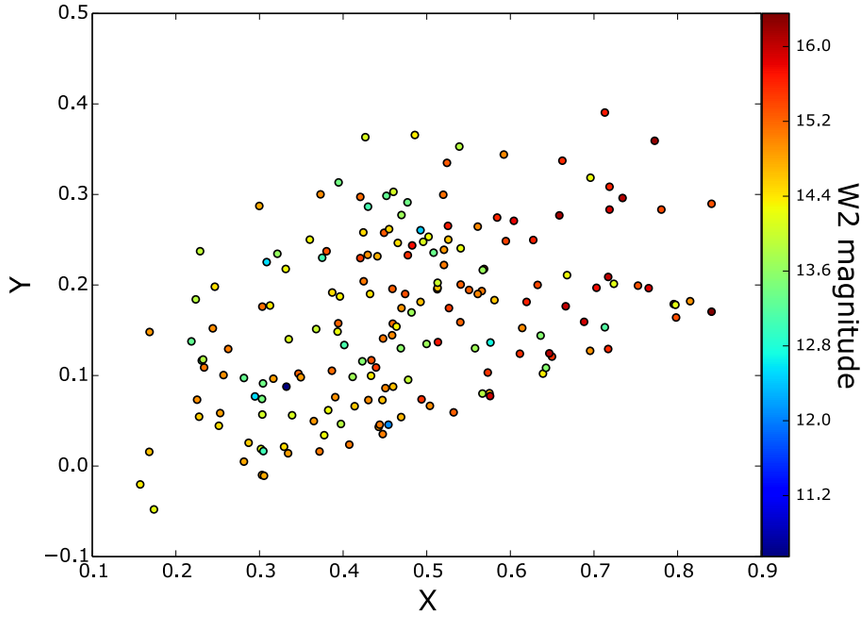
- Variability pattern in the near-IR band can be used to identify AGN (Cioni+13, Ivanov+16)
- Multi-epoch Ks band data
- Reference sample less variable and less luminous

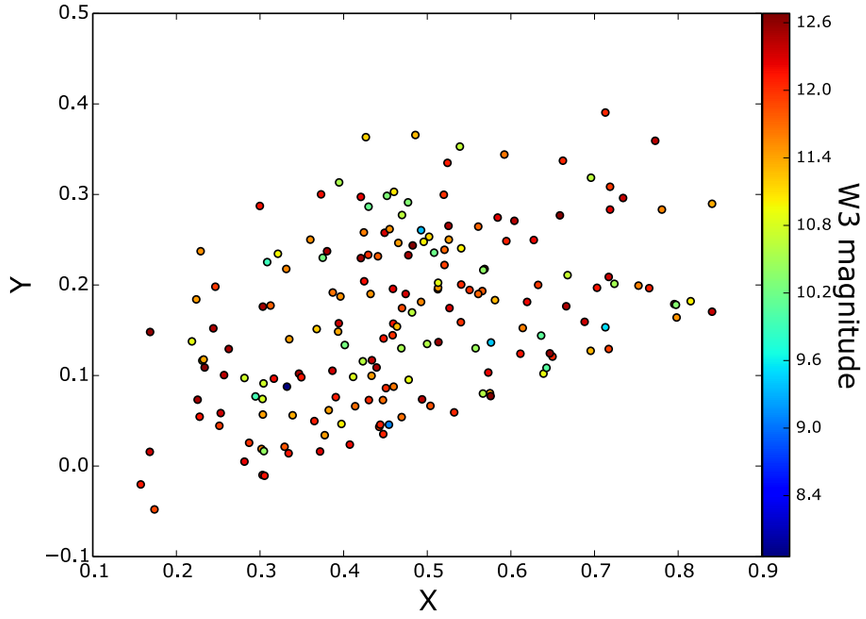


Multi-wavelength properties



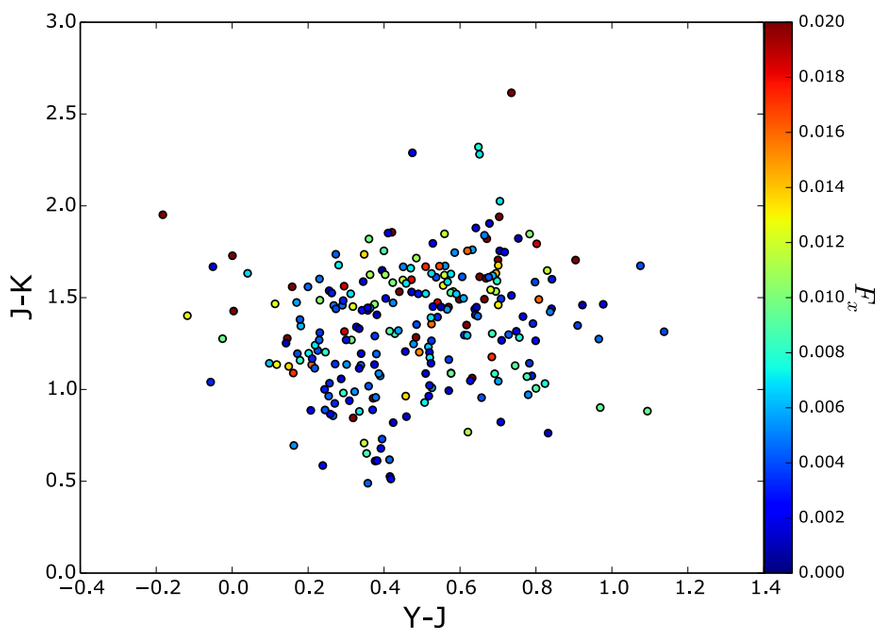


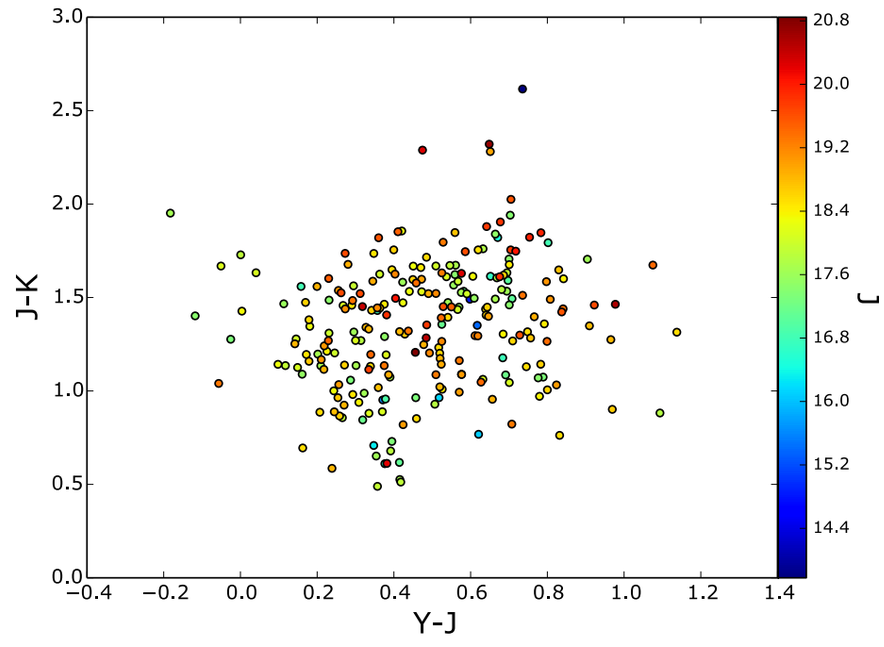


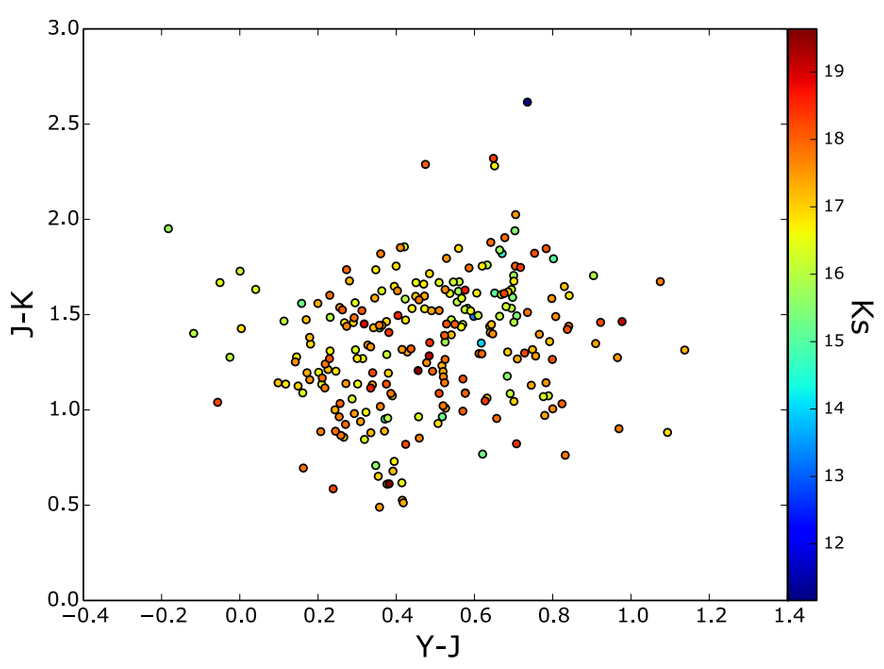


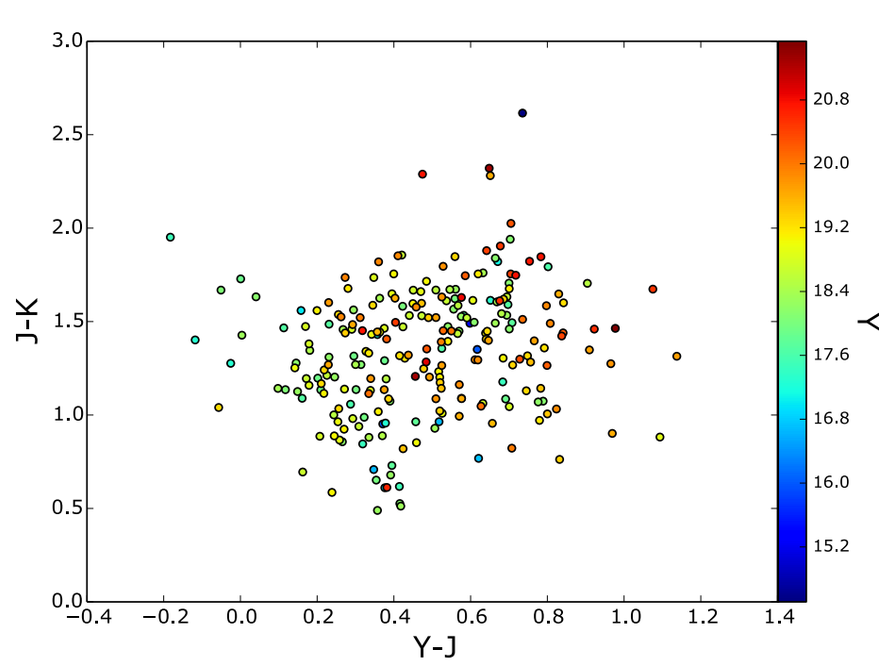
x≡log(f12um)/(f4.6um) & y≡log(f4.6um)/(f3.4um)

Multi-wavelength properties





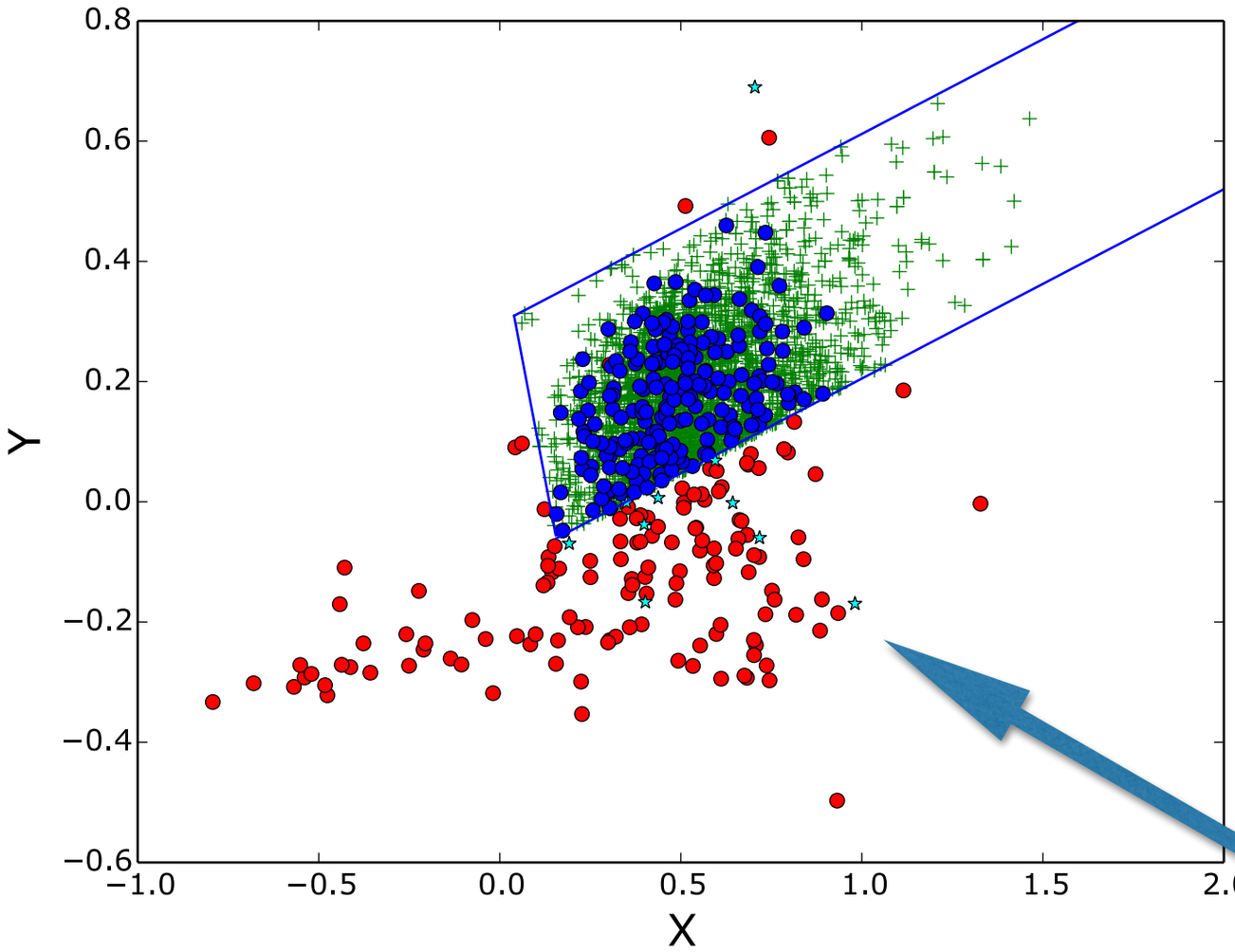




Completeness of the sample

- BULK of sources identified in the MCs expected to be AGNs: > 71% in SMC : 3158 of 4449 sources expected
- Only 276 identified!!!
- 1989 AGN candidates from Sturm+13 not confirmed in this work
- Limitations of the selection criterion & the samples
- AGN wedge of Mateos+12 defined using BUXS; also more sensitive to type I AGN than type II

Completeness of the sample

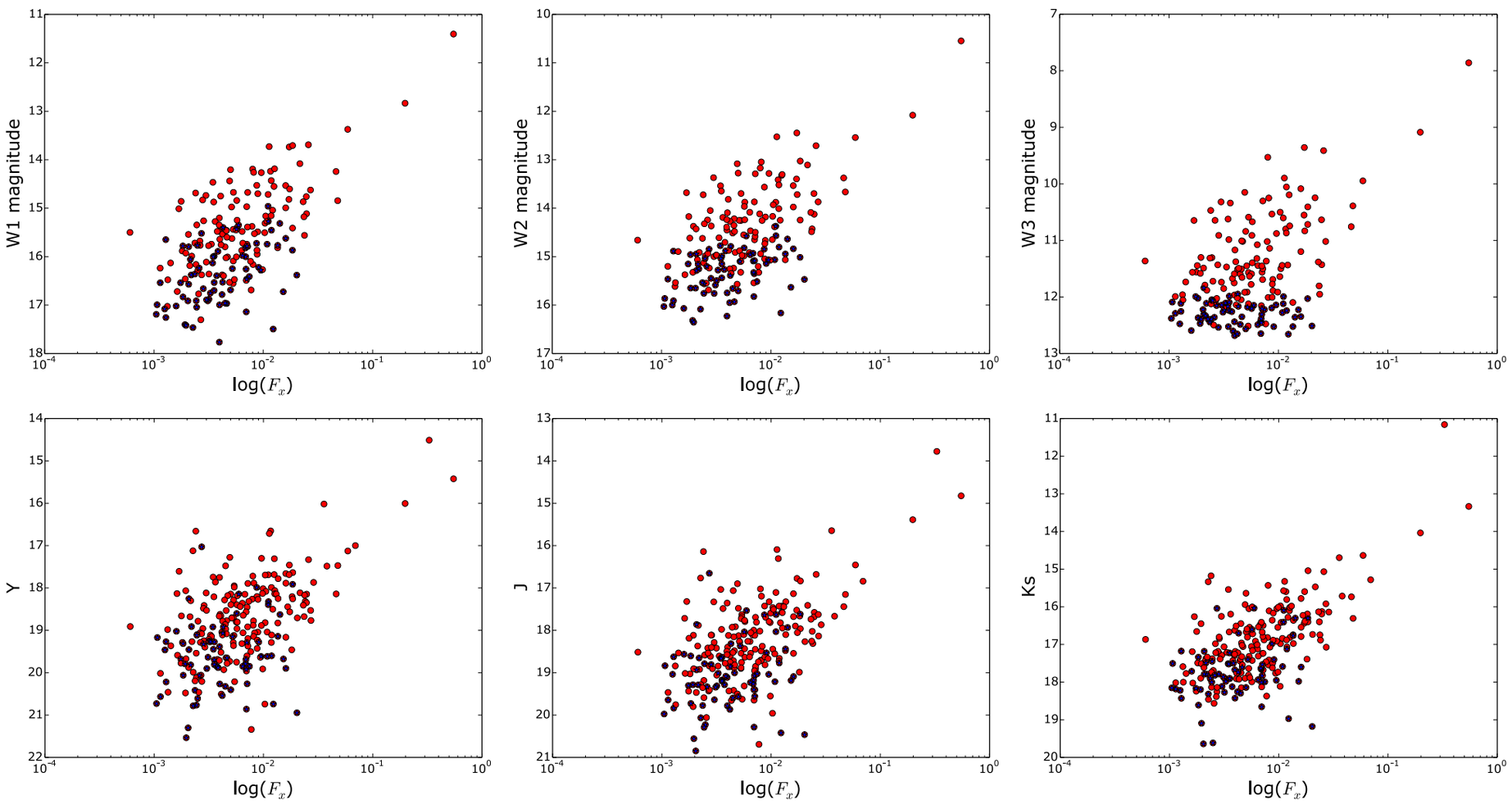


x≡log(f12um)/(f4.6um) & y≡log(f4.6um)/(f3.4um)

Green: all ALLWISE selected AGN within the area
Blue: with X-ray counterparts
Red: AGN candidate not confirmed in this work
134 matches out of 1989
Cyan: ALLWISE counterparts of HMQ selected sources
10 matches out of 58

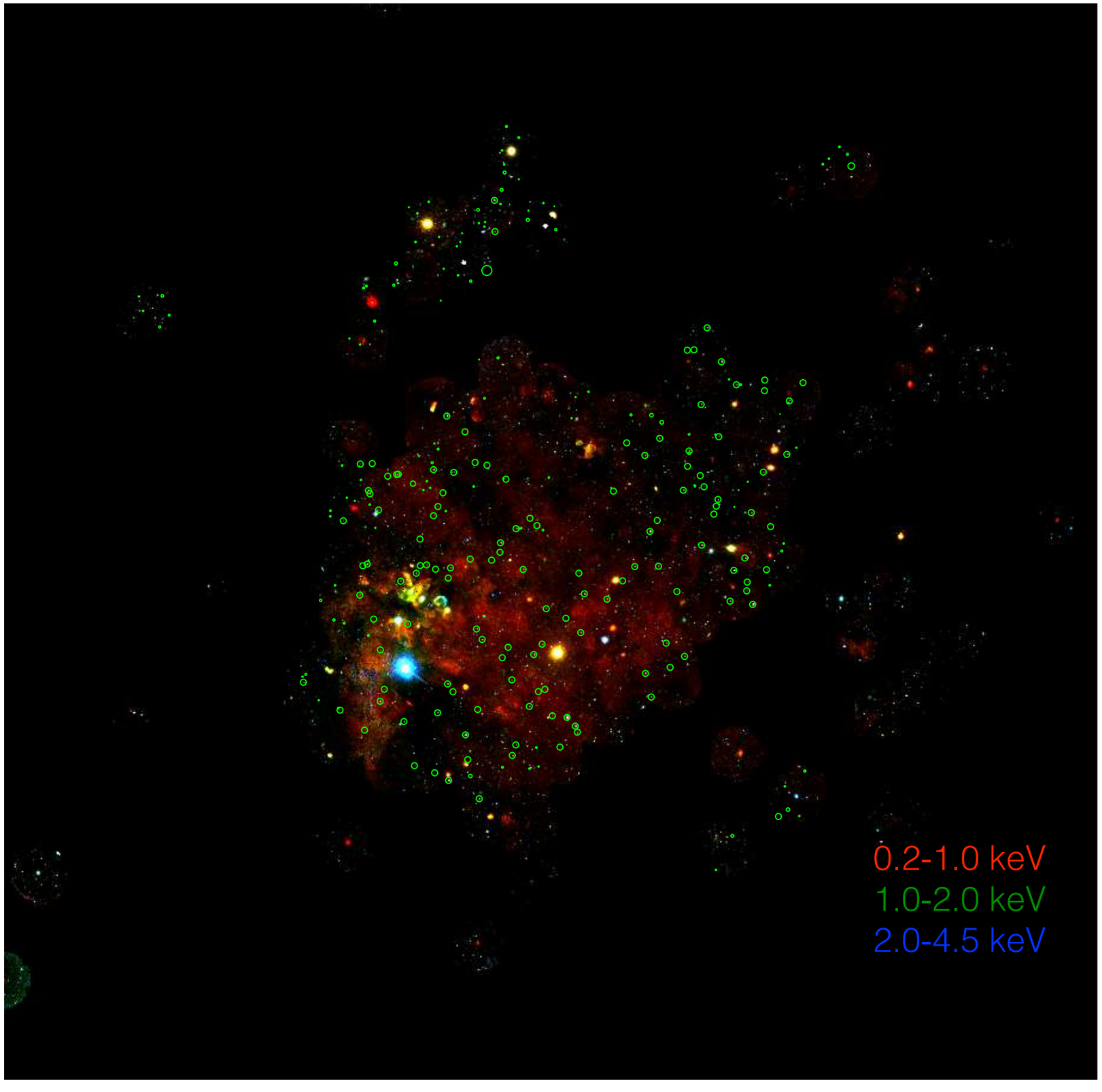
Horizontal sequence of normal galaxies in the ALLWISE colour-colour space

Completeness of the sample



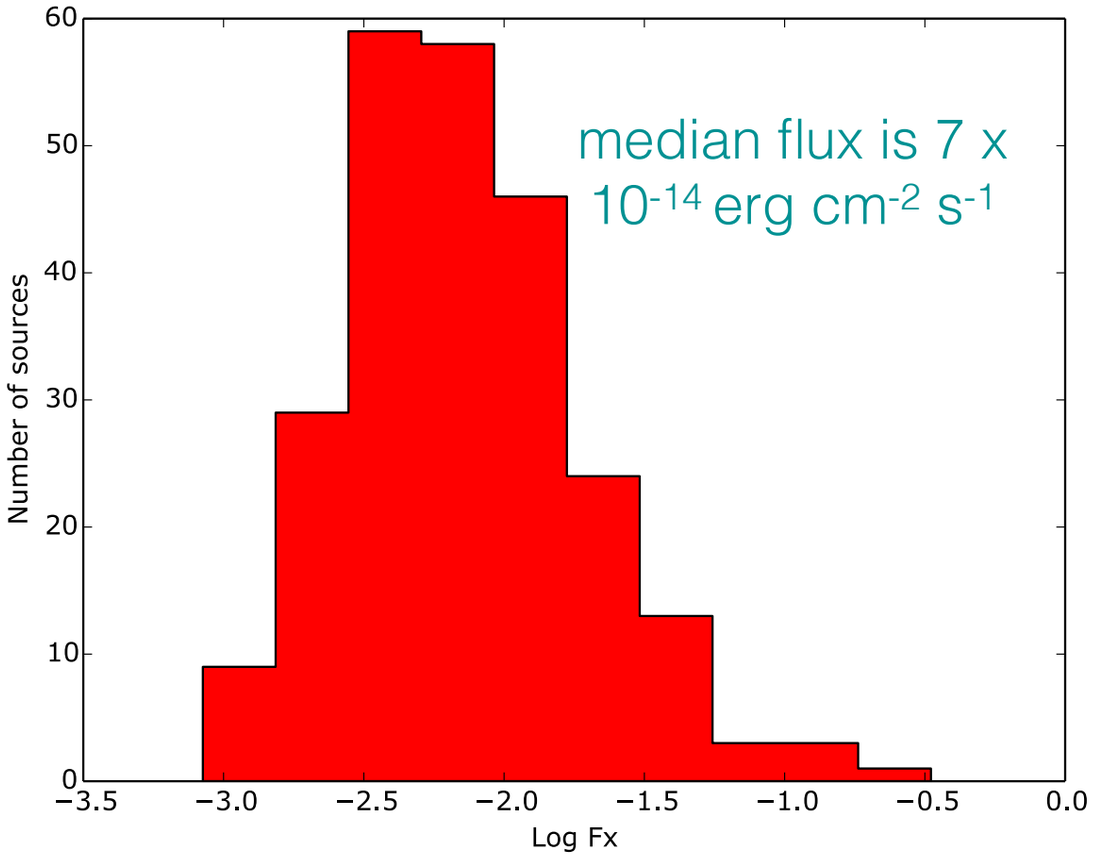
Blue: new candidates: faint sources : Many sources near the detection thresholds missed?

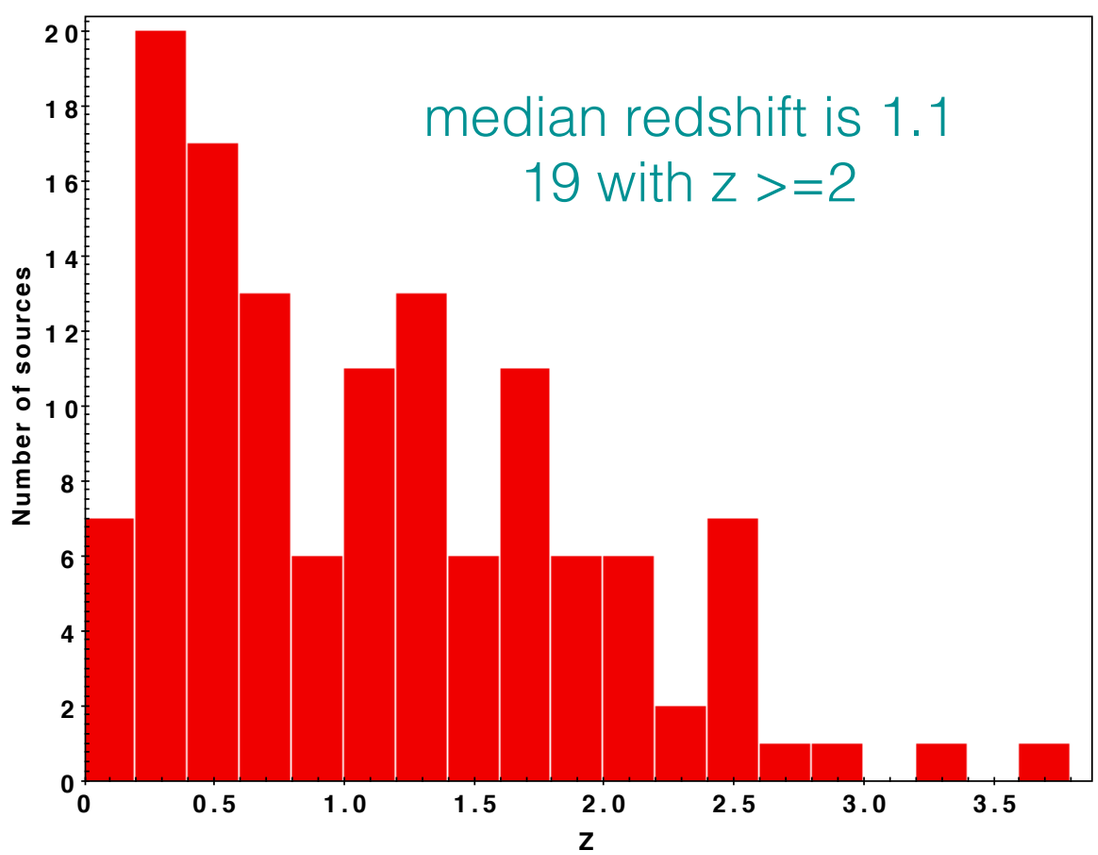
X-ray selected AGNs behind the LMC

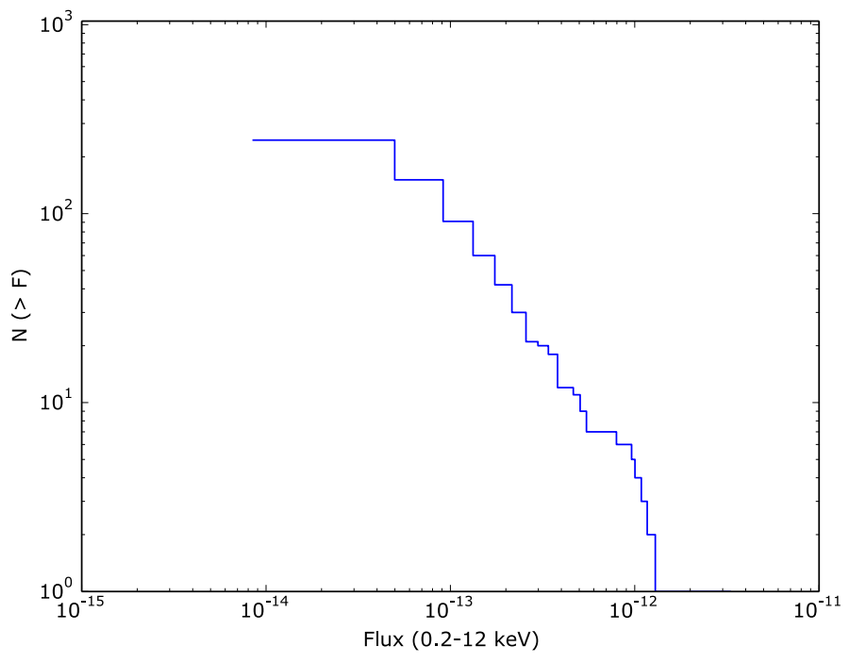


- LMC: ~13 deg^2
- 321 XMM-*Newton* pointings
- 245 sources identified
- astrometric corrections performed

Flux and z distribution (PRELIMINARY)

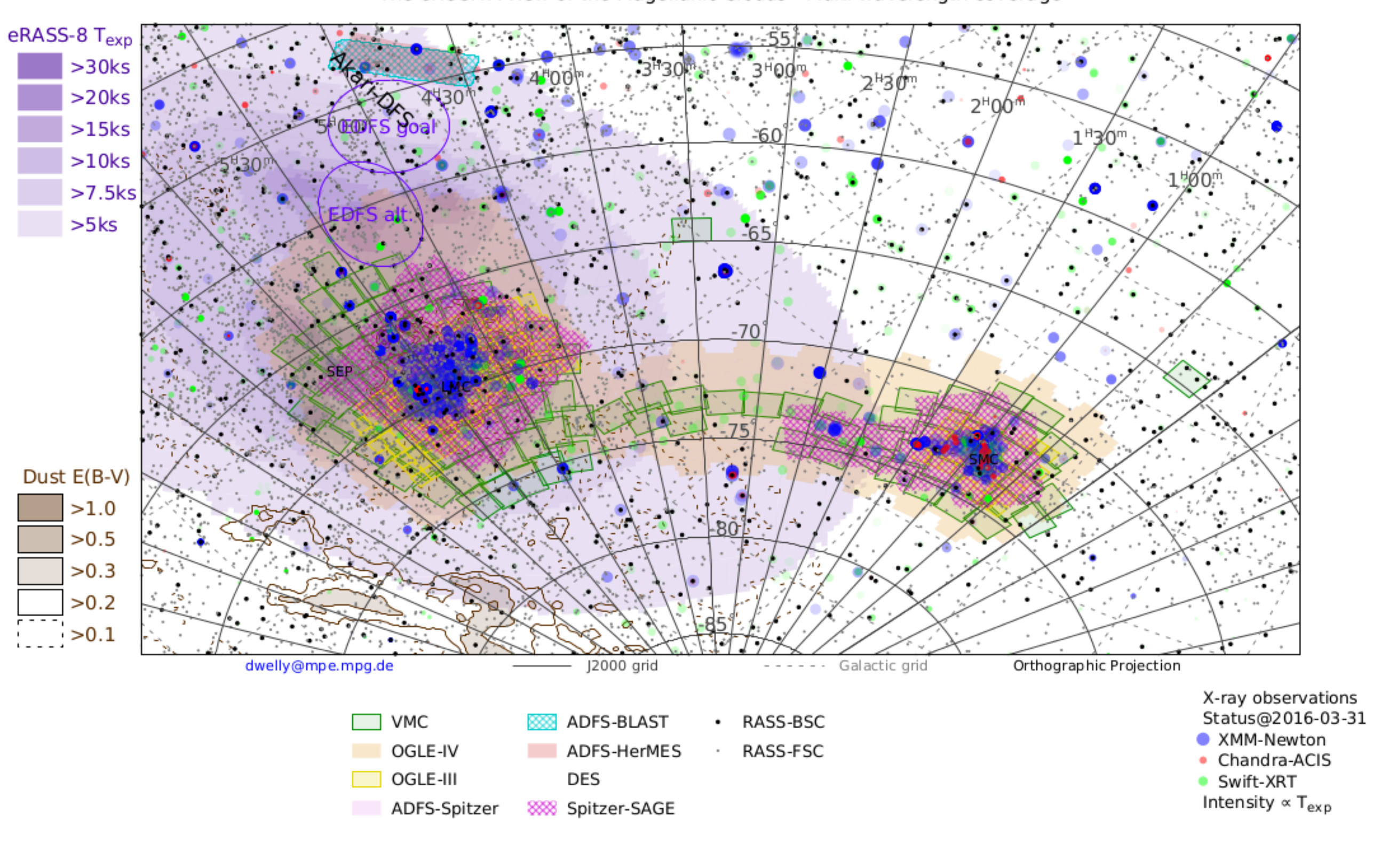






From XMM: Assuming homogenous distribution~ 19 AGNs/ sq. degree

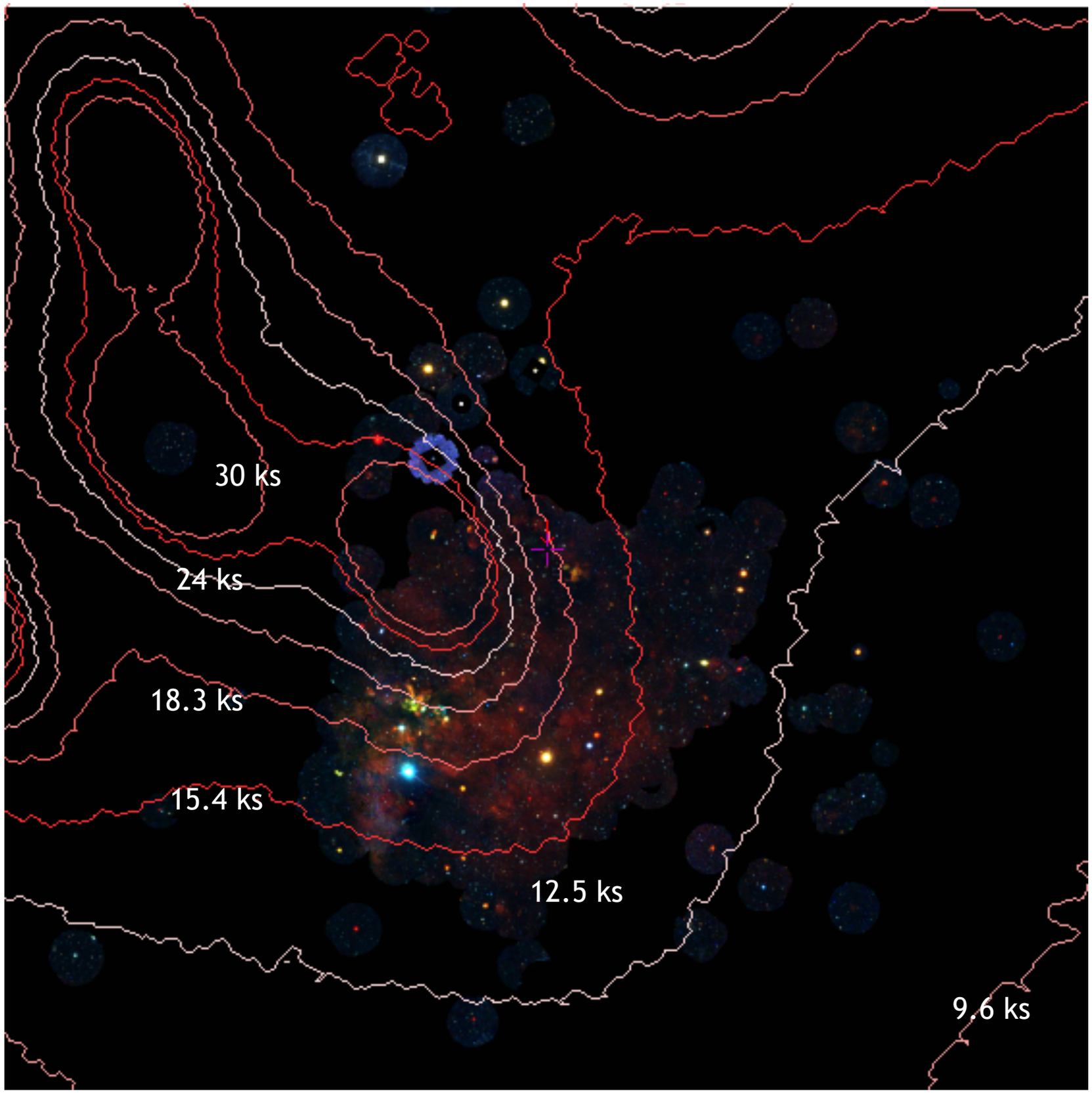
Near Future


The eROSITA view of the Magellanic Clouds - Multi-wavelength coverage
eRASS-8 T_exp
>30ks
>20ks
>15ks
>10ks
>7.5ks
>5ks
Akari-DFS
EDFS goal
EDFS alt.
SEP
LMC
SMC
-55
-60
-65
-70
-75
-80
-85
4H00m
3H30m
3H00m
2H30m
2H00m
1H30m
1H00m
5H30m
4H30m
5H00m
Dust E(B-V)
>1.0
>0.5
>0.3
>0.2
>0.1
dwelly@mpe.mpg.de
J2000 grid
Galactic grid
Orthographic Projection
VMC
OGLE-IV
OGLE-III
ADFS-Spitzer
ADFS-BLAST
ADFS-HerMES
DES
Spitzer-SAGE
RASS-BSC
RASS-FSC
X-ray observations
Status@2016-03-31
XMM-Newton
Chandra-ACIS
Swift-XRT
Intensity ∝ T_exp

SUMMARY

- Finding AGN behind the Magellanic Clouds is not easy..current study increases the census of AGN / X-ray associations behind the Magellanic Clouds significantly
- Existing high confidence AGN catalogues (HMQ/MILLIQUAS) contains only a small fraction of X-ray associations
- Identified candidate AGN (81) and obscured high luminosity quasars (13 CT AGN candidates) —–> dedicated followup
- Important for reference sources in the MCs for the astrometry reference catalogue for eROSITA
- Bright AGN can be studied with eROSITA,
- Detailed study of AGN population behind the LMC with eROSITA

eROSITA survey of the Magellanic clouds

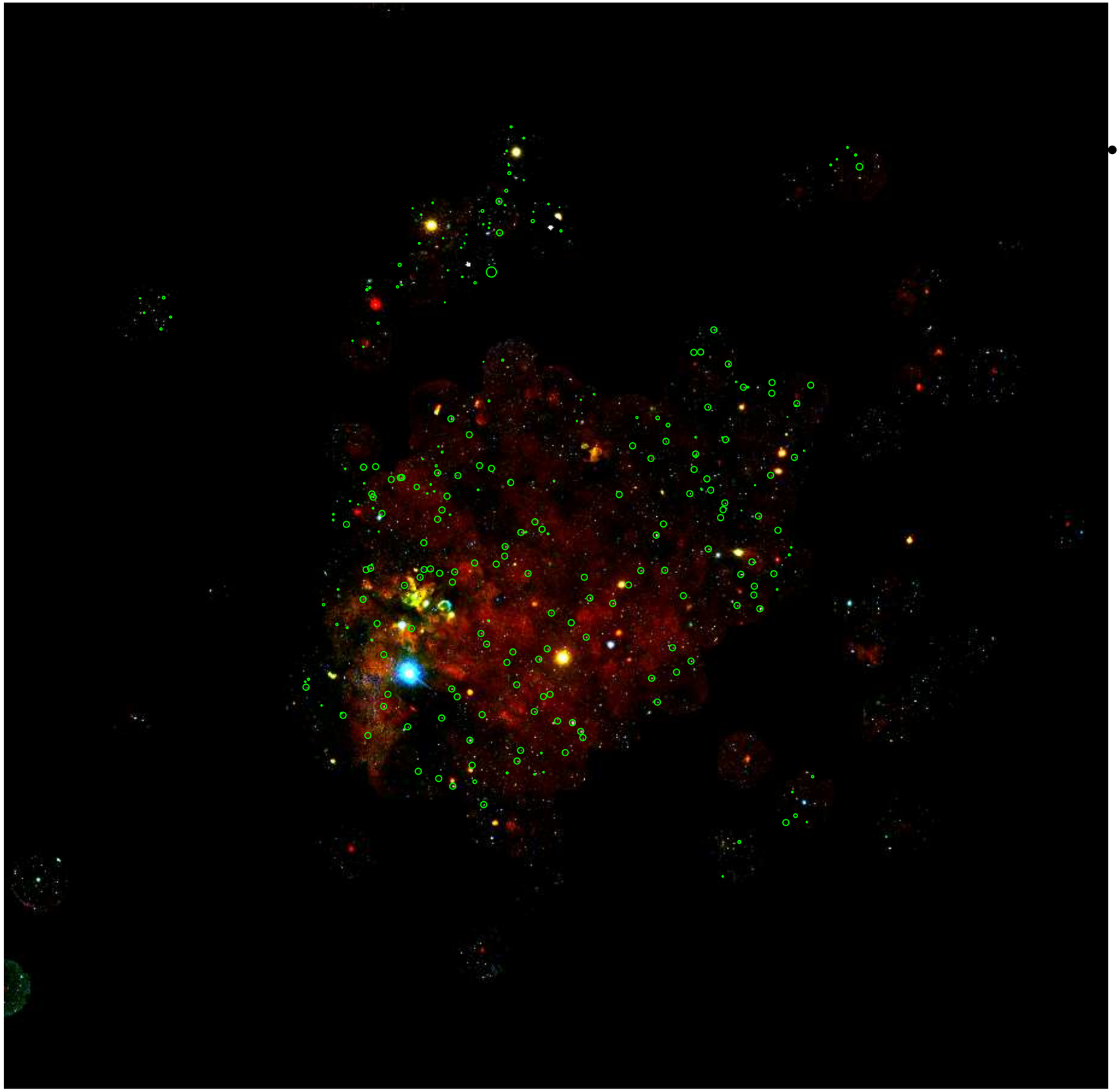


LMC

eROSITA survey:

- Complete coverage
- Multiple coverage
- Similar exposure after 4 years as XMM

eROSITA survey of the Magellanic clouds

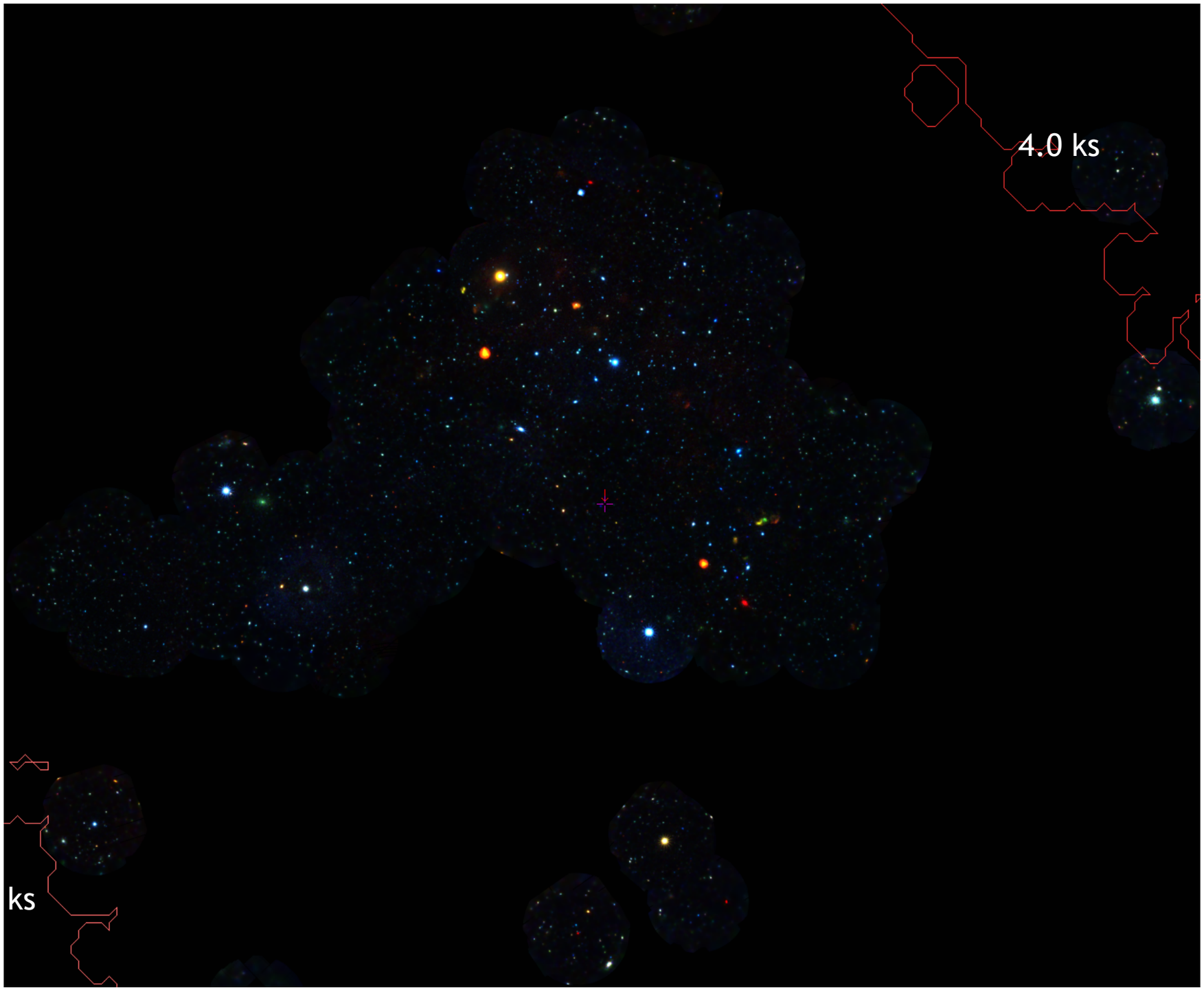


LMC

XMM survey:

- 245 AGNs selected with X-ray associations

eROSITA survey of the Magellanic clouds

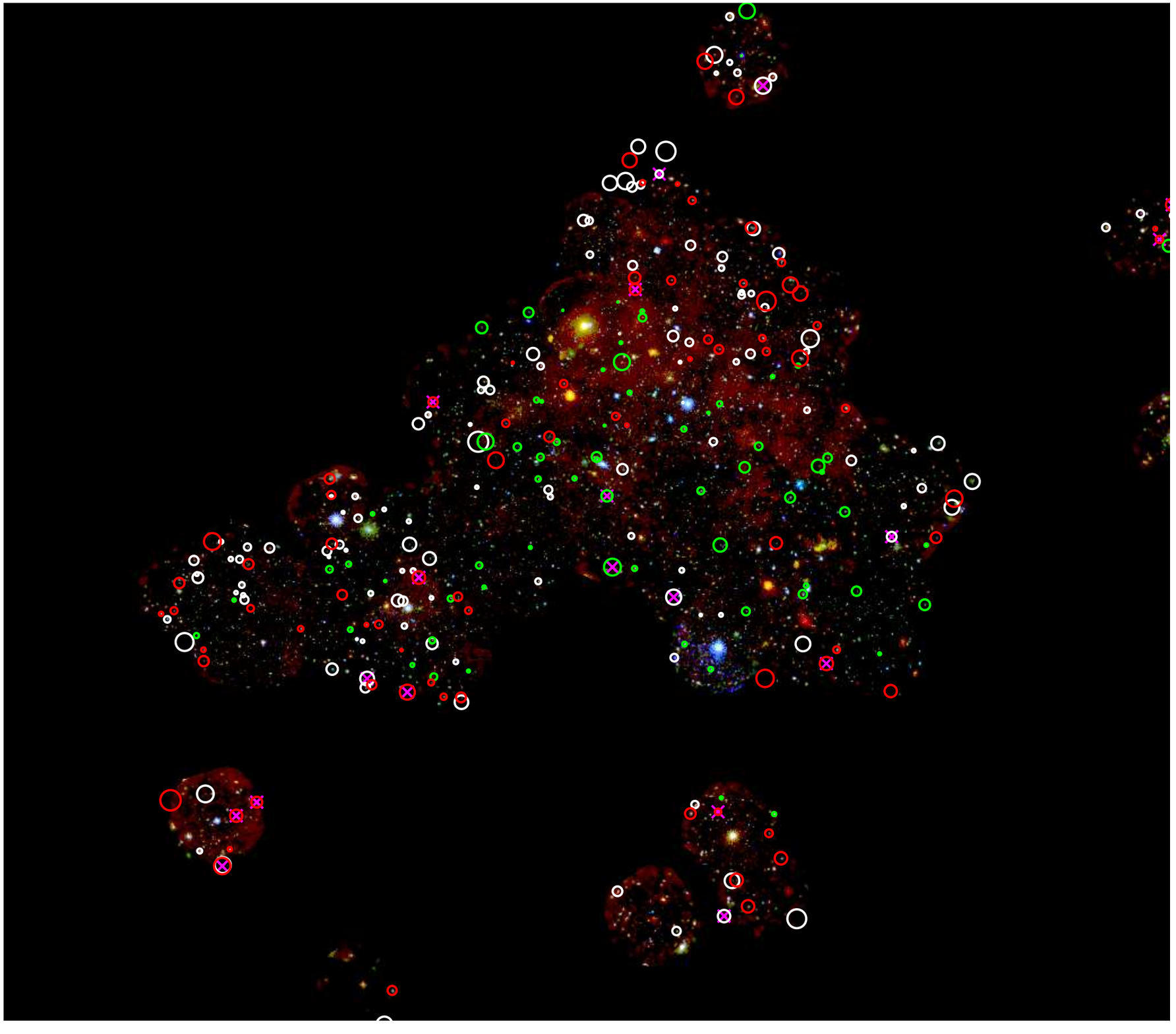


SMC

eROSITA survey:

- Complete coverage
- 8 surveys
- 4 ks exposure (XMM ~ 20 ks)

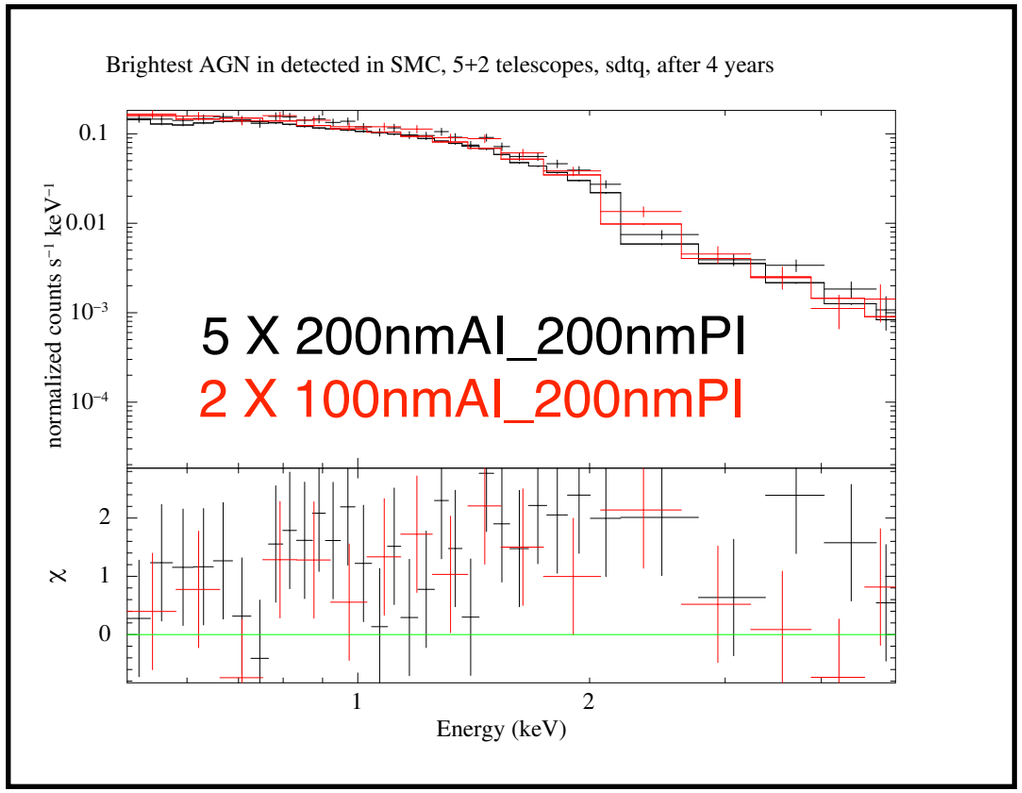
eROSITA survey of the Magellanic clouds

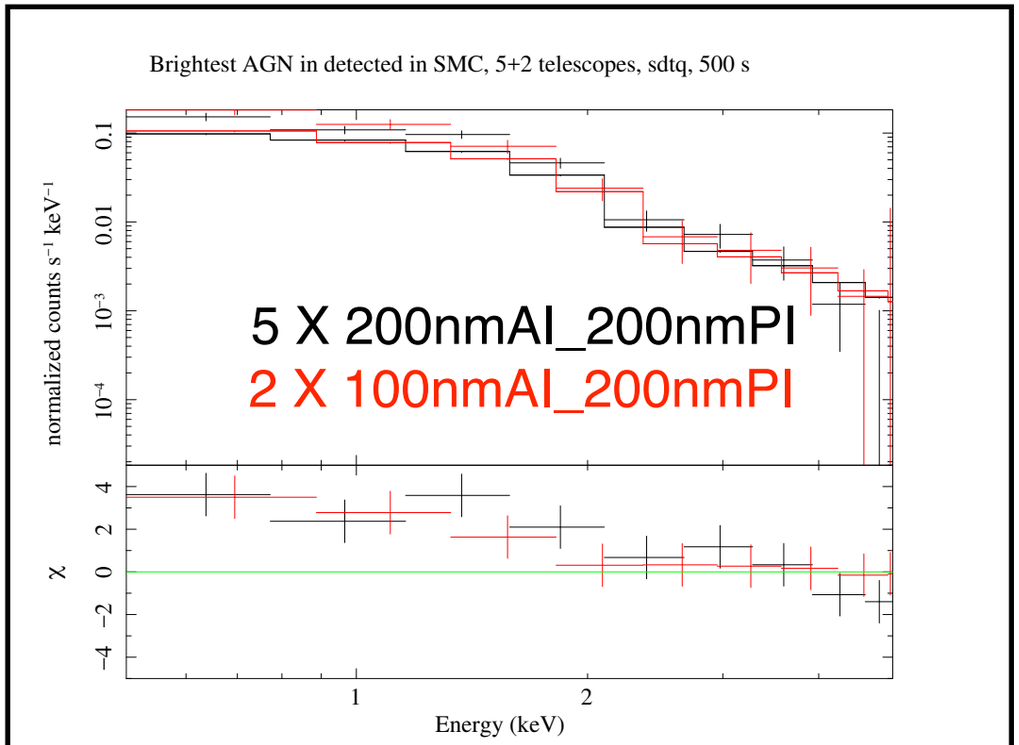


SMC

XMM survey
Complete coverage
270 AGNS identified with
X-ray associations

AGN behind the SMC as seen with eROSITA





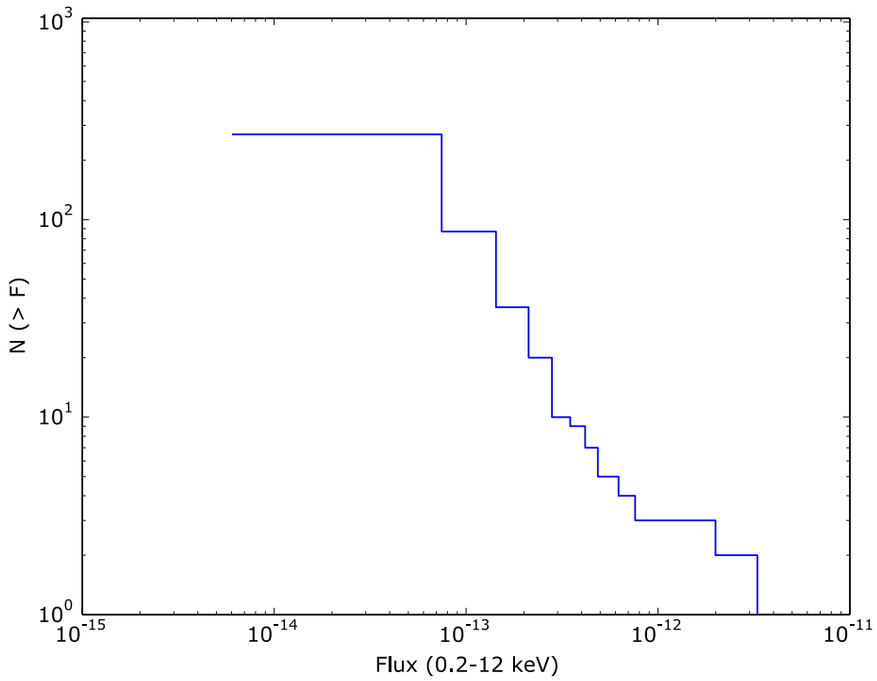
flux ~ 5 x 10^{-12} erg cm^{-2} s^{-1}

Γ=1.8 ± 0.2

2 x 0.20 c/s ; 5 x 0.19 c/s

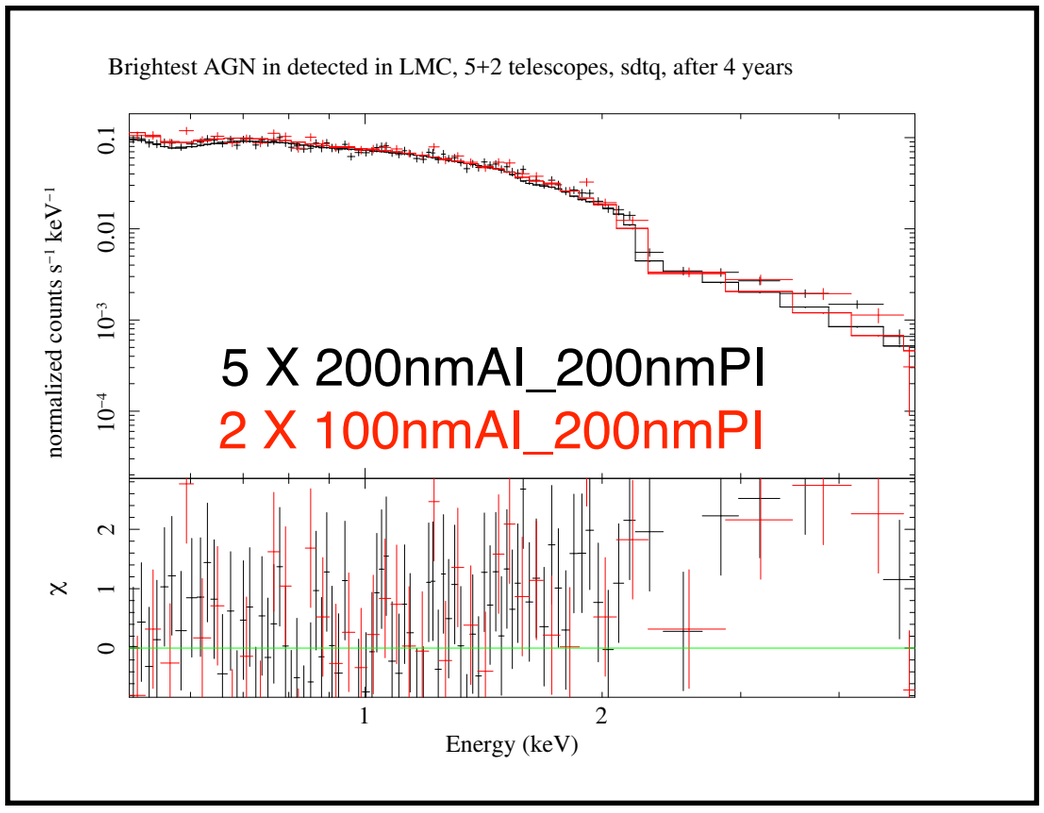
500 s visit: 675 counts

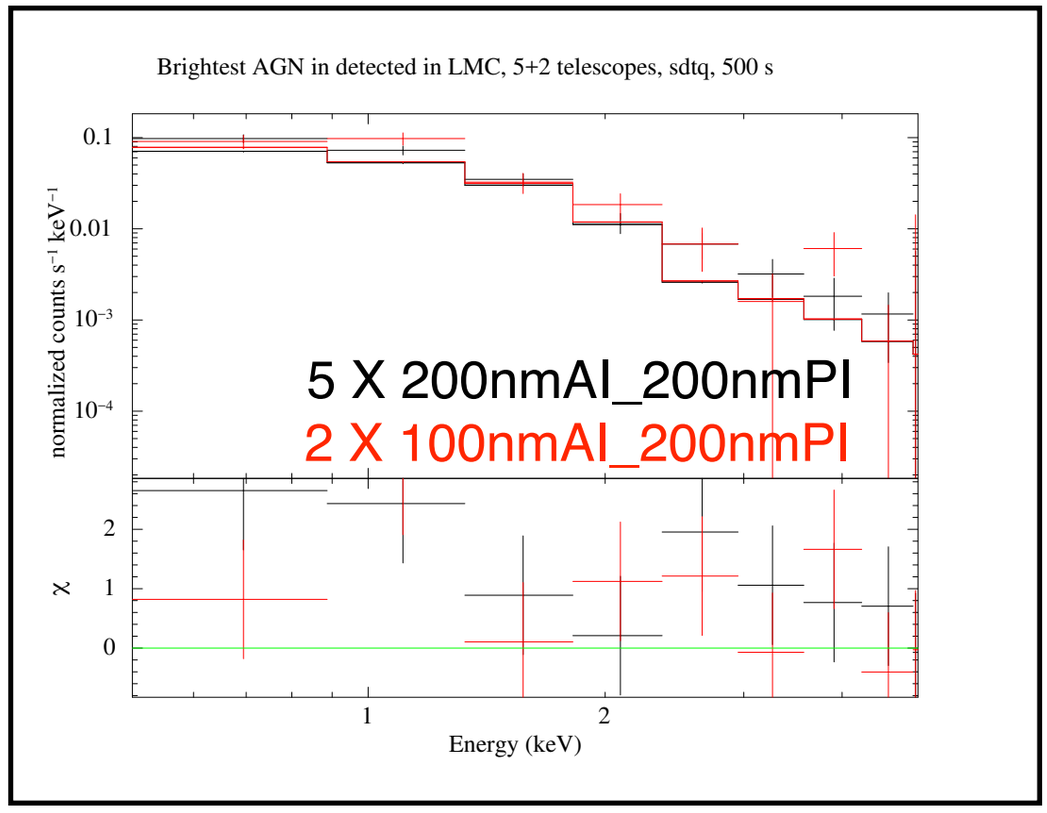
after 4 years: 5400 counts



From XMM: Assuming homogenous distribution~ 41 AGNs/ sq. degree

AGN behind the LMC as seen with eROSITA





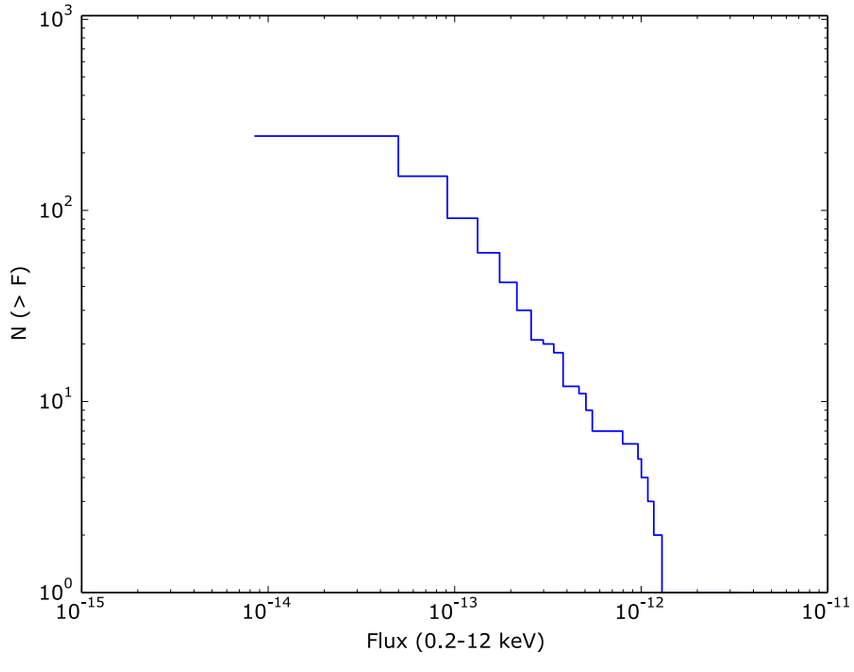
flux ~ 3 x 10^{-12} erg cm^{-2} s^{-1} Γ=1.88 ± 0.09

2 x 0.11 c/s ; 5 x 0.10 c/s

500 s visit: 360 counts

after 4 years: 14400 counts

median flux of the sample ~ 10^{-14} erg cm^{-2} s^{-1} : 144 counts



From XMM: Assuming homogenous distribution~ 19 AGNs/ sq. degree