THE LARGEST X-RAY SURVEY

PHOTOMETRIC REDSHIFTS (AND SPECTRAL FITS) FOR THE 3XMM CATALOGUE - ESA PRODEX

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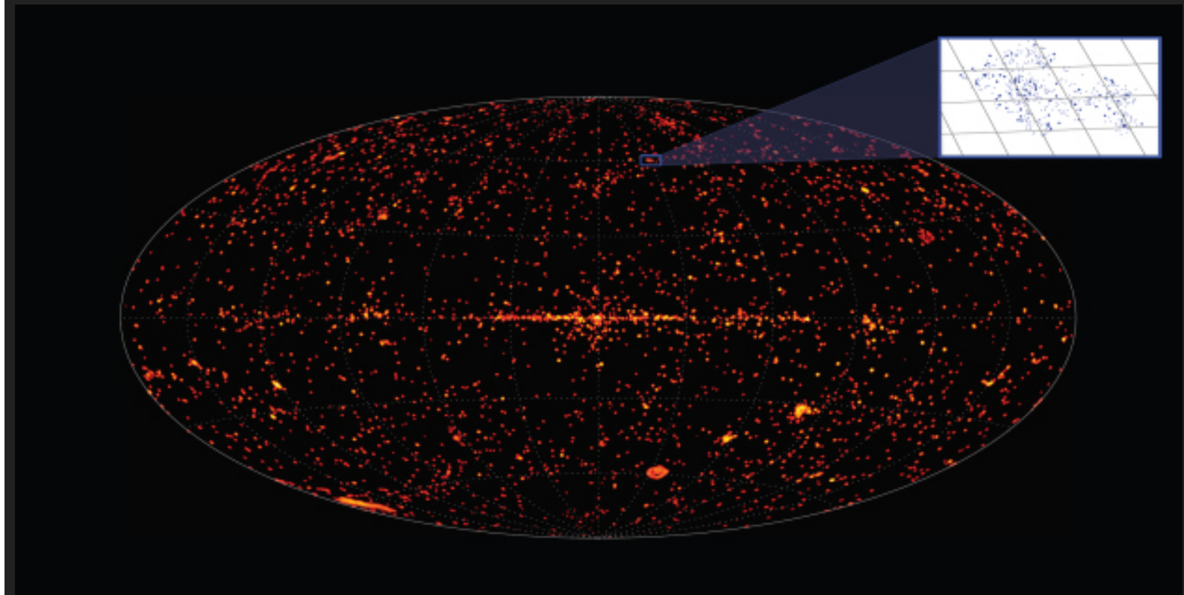
TALK OUTLINE

- The scope of the project
- Brief Description of the 3 XMM - (DR7) catalogue
- comparison with other X-ray surveys (and eROSITA)
- Machine Learning Photometric redshifts (TPZ)
- Description of Optical/IR photometric catalogues used
- spectroscopic training samples
- scientific potential

THE 3XMM CATALOGUE



DISTRIBUTION ON THE SKY OF ALL XMM POINTINGS

median flux ~1e-14 2-10 keV

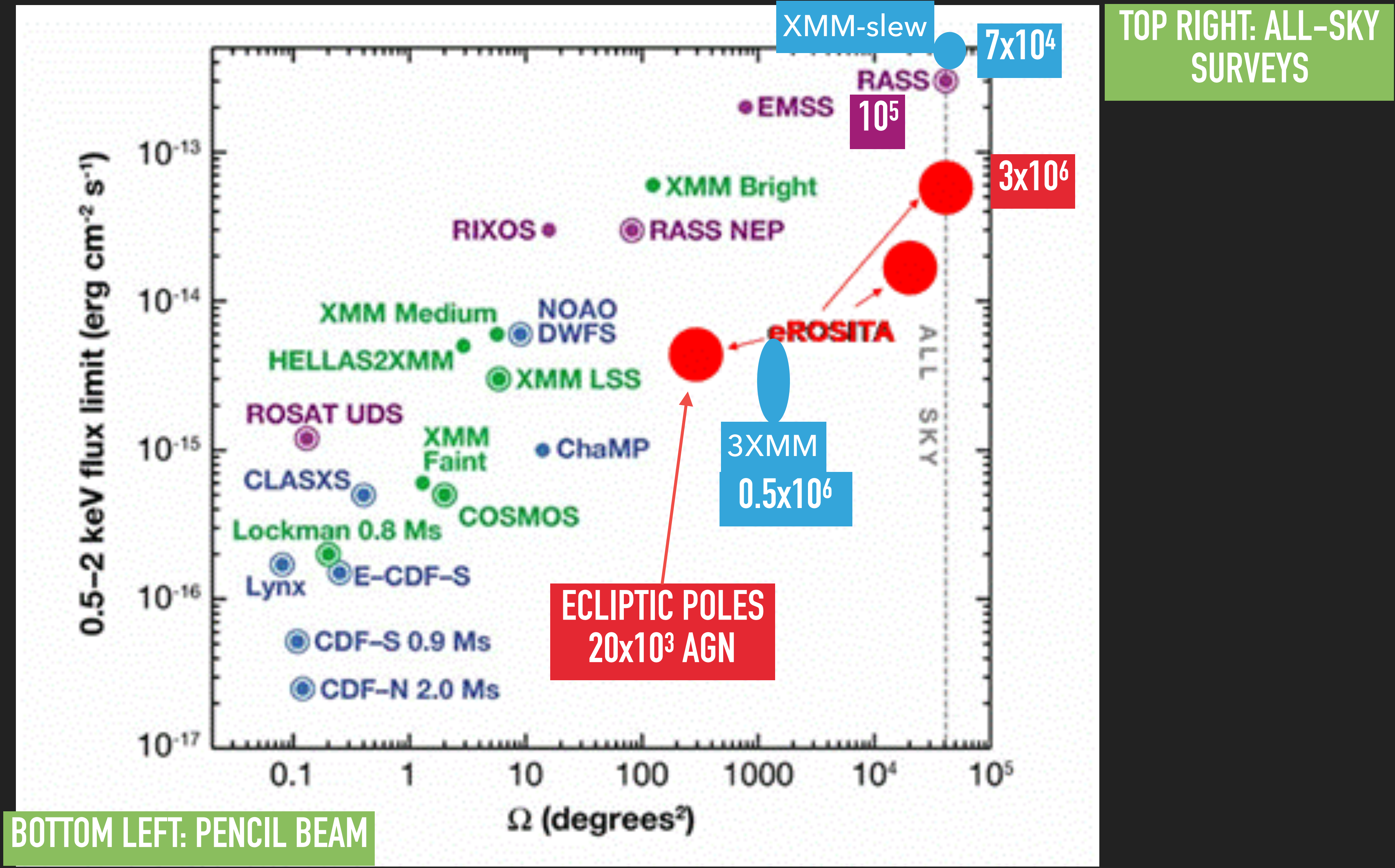
- ~2% of the sky or 1032 sq. degrees
- 10,000 pointings,
- 500,000 unique sources
- 170,000 sources with X-ray spectra

XMM LARGE AREA SURVEYS

- COSMOS survey 2 sq. degrees 50ksec : 2000 sources
- XMM/ATLAS 7 sq. degrees 5 ksec : 2000 sources
- Stripe-82 32 sq. degrees :
- XMM/XXL 2 x 25 sq. degrees 10 ksec : 17,000 sources
- 3XMM ~1000 sq. degrees 500,000 sources

THE BACKGROUND IS THE XMM/ATLAS TRUE COLOUR 7 deg^2 MOSAIC IMAGE

ATLAS OF X-RAY SURVEYS



DISTANCES (REDSHIFTS) ARE NECESSARY TO RELEASE THE POTENTIAL OF 3XMM AS A SURVEY TOOL

PHOTOMETRIC REDSHIFT TECHNIQUES (FOR X-RAY SOURCES)

- Spectral Energy Distribution fitting (Salvato+, Hsu+ using LePhare) applied to e.g. COSMOS , CDFS

  PLUS: no training sample necessary

  MINUS: very careful source matching and photometry i.e. time consuming

- Machine Learning (e.g. **TPZ**, Kind Carrasco+13, Dameware, Brescia+15, **AnnZ**, Colllister+04)

  PLUS: photometry requirements not rigorous as long as training sample has identical photometry

  MINUS: large training sets are required

NO MACHINE LEARNING TECHNIQUES APPLIED TO X-RAY SOURCES BEFORE

mainly because the training samples were scarce.

We use the TPZ Algorithm (Trees for photo-z , Kind Carrasco & Brunner 2013)

OPTICAL PHOTOMETRY

- SDSS (~10,000deg2) u,g,r,i,z (r_{AB}~22.2)
- PANSTARRS (3π) g,r,i,z,Y
- near-IR (VISTA, ukidss): J, H, K
- + UKIDSS J,H,K
- WISE (all-sky) : W1 (3.6μm), W2 (4.5μ**m)**
- **Future work will include deeper optical observations in KIDS (25) deg2 , SDSS Stripe-82 (30deg2) (and eventually DES 100deg2), with r~24.5-25**

MATCHING BETWEEN X-RAY AND OPTICAL SOURCE CATALOGUES

The XMATCH Bayesian matching tool (ARCHES EU FP7) between multiple catalogues (e.g. X-ray, optical, near-IR assigning a probability for the multi-source match

This takes into account the catalogue positional error and the source density of the matching catalogues (for details see Pineau et al. 2016). WE KEEP ALL SOURCES P>0.7

This may be fine for the current optical depths probed but going deeper one needs to take into account the varying surface density with optical magnitude (e.g. NWAY, XMATCH upgrade).

PANSTARRS

- PANSTARRS 95k (Gal. lat. |b|>20)
- 65k with >7 bands

bands	No	Filters	+Filters
10	20103	grizY	JHKw1w2
8	5984	grizY	JHK
7	38949	grizY	w1w2
5	29117	grizY	

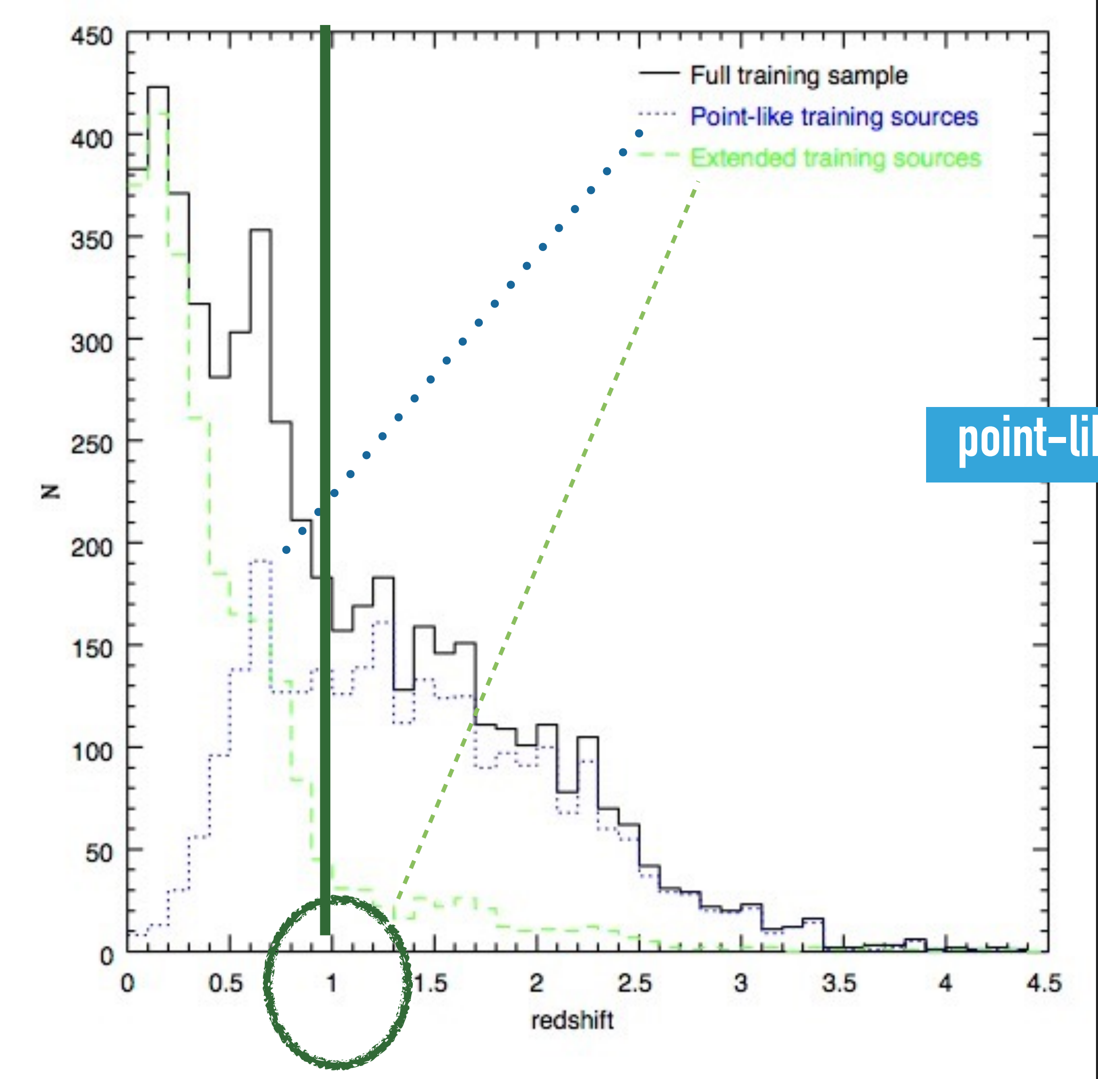
STARS AGAINST GALAXIES

- Methods that could be employed:
- 1. optical vs. near-IR colours
- 2. Fx/Fopt
- 3. Proper motions (Tian+17) using GAIA

TRAINING SAMPLE

- XMM/XXL survey North 25deg2
- spectroscopic redshifts have been obtained with SDSS specifically for the X-ray sources
- 2512 AGN Menzel et al. 2016
- sample increased with XWAS (Esquej 2013), XBS (DellaCeca 2004), XMS (Barcons 2007), XMM-COSMOS (Brusa 2010) , optically selected X-ray AGN

TRAINING: REDSHIFT DISTRIBUTION



point-like sources occupy higher redshifts

PERFORMANCE SUMMARY

	SDDS t.s.		Pan-STARRS t.s.	
# bands	σ_{NMAD}	eta(%)	σ_{NMAD}	eta(%)
Point-like sources				
5	0.076	29	0.138	41
7	0.064	19	0.088	25
8	0.057	20	0.074	26
10	0.049	14	0.062	17
Extended sources				
5	0.071	18	0.063	13
7	0.057	14	0.038	6
8	0.054	12	0.052	9
10	0.046	9	0.036	4

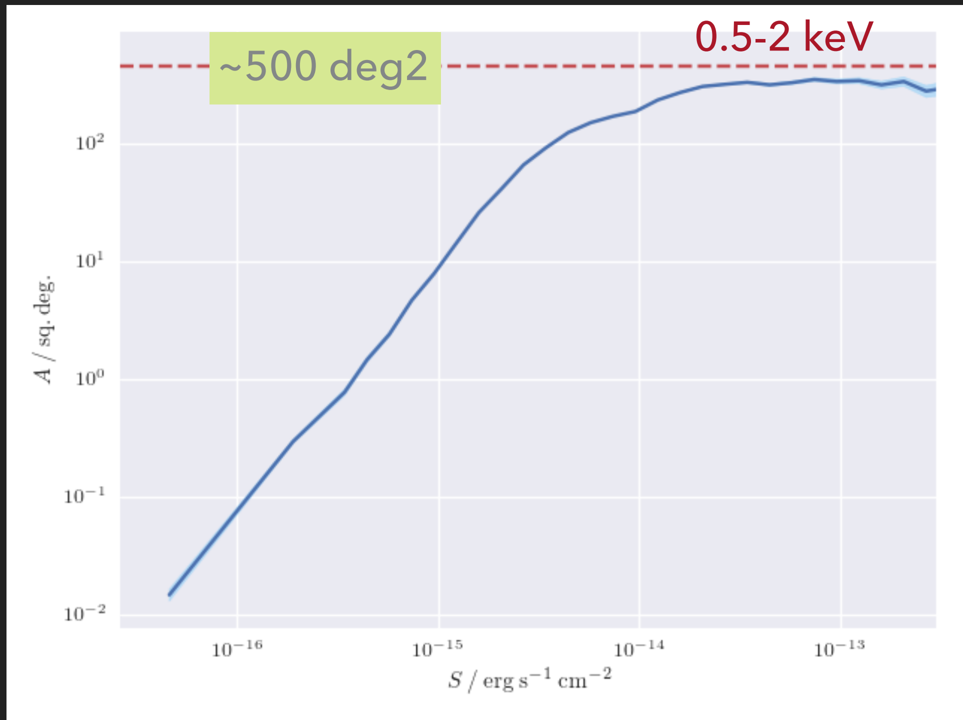
- Extended sources behave better than point-like sources
- The more the bands the better, both in number of outliers and σ
- These numbers can improve by applying a cut in z-conf (which is a measure of extent of the PDF). this cut at the cost of reducing the sample size of course

OF COURSE THE KEY FOR THE PERFORMANCE IS THE TRAINING SAMPLE SIZE

AREA CURVES

Indirect way: if we know the logN-logS we derive the area curve

- Based on the XMM/SDSS (120deg2) by Georgakakis 2011 where thelogN-logS is well-known (unweighted flux distribution X area curve= logN-logS)
- If the logN-logS is known, this implies that the area curve is well constrained
- However, stars should be first taken out
- (the Tian sample has not been used here)



PHOT-Z ARE THE BASIS FOR OUR X-RAY SPECTRAL FITS

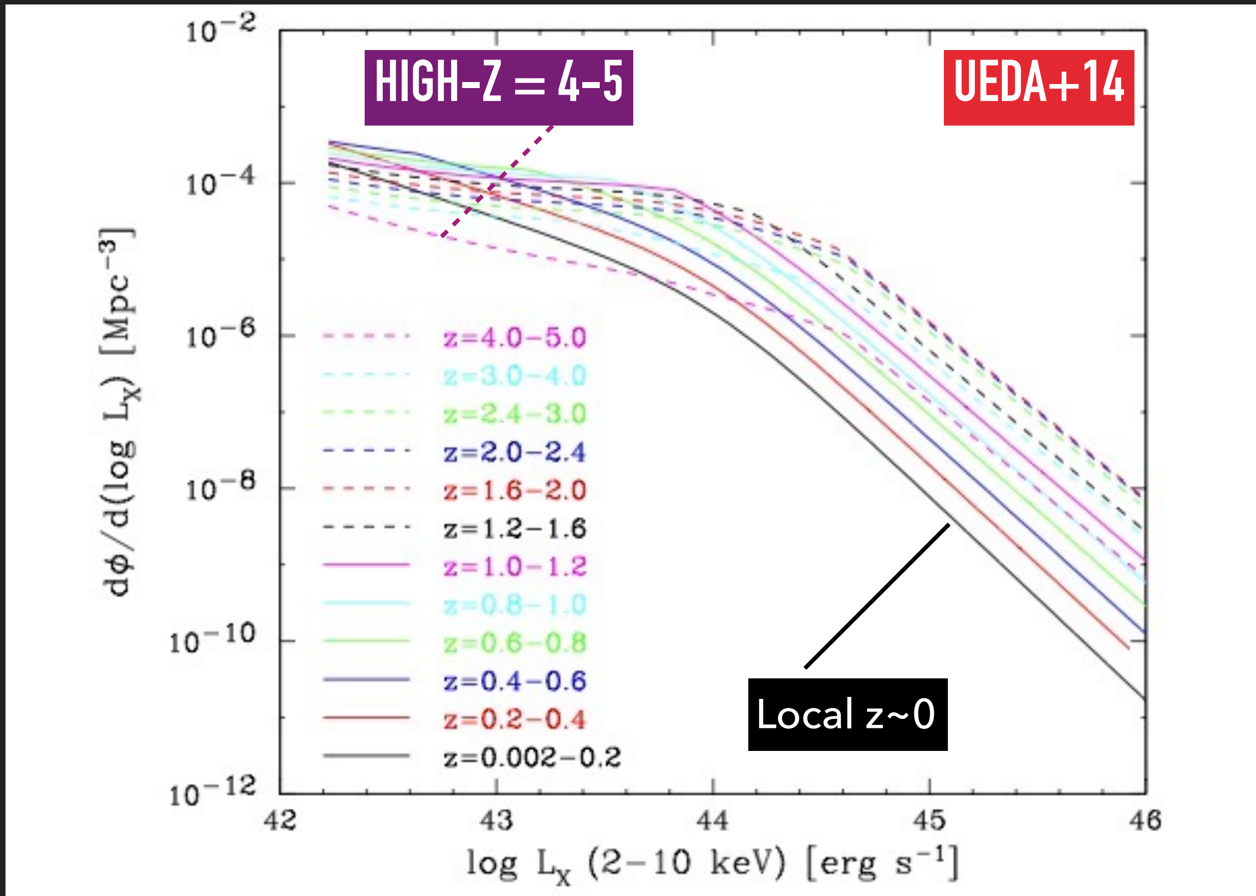
- We use the (Bayesian) BXA software by Buchner et al.
- PYTHON scripts to perform Spectral fits using SHERPA
- Simple spectral models . The spectral parameters errors take into account the phot-z uncertainties as well

SCIENCE : LUMINOSITY FUNCTION

- AGN Luminosity function (LF)
- Previous derivations examples include Ueda+14, Miyaji+15, Fotopoulou+16, Buchner+16, Ranalli+16, Aird+15 involving a few thousand sources

X-RAY LUMINOSITY FUNCTION: WHAT WE LEARNED & OPEN QUESTIONS

- X-ray LF: double power-law, evolving with redshift

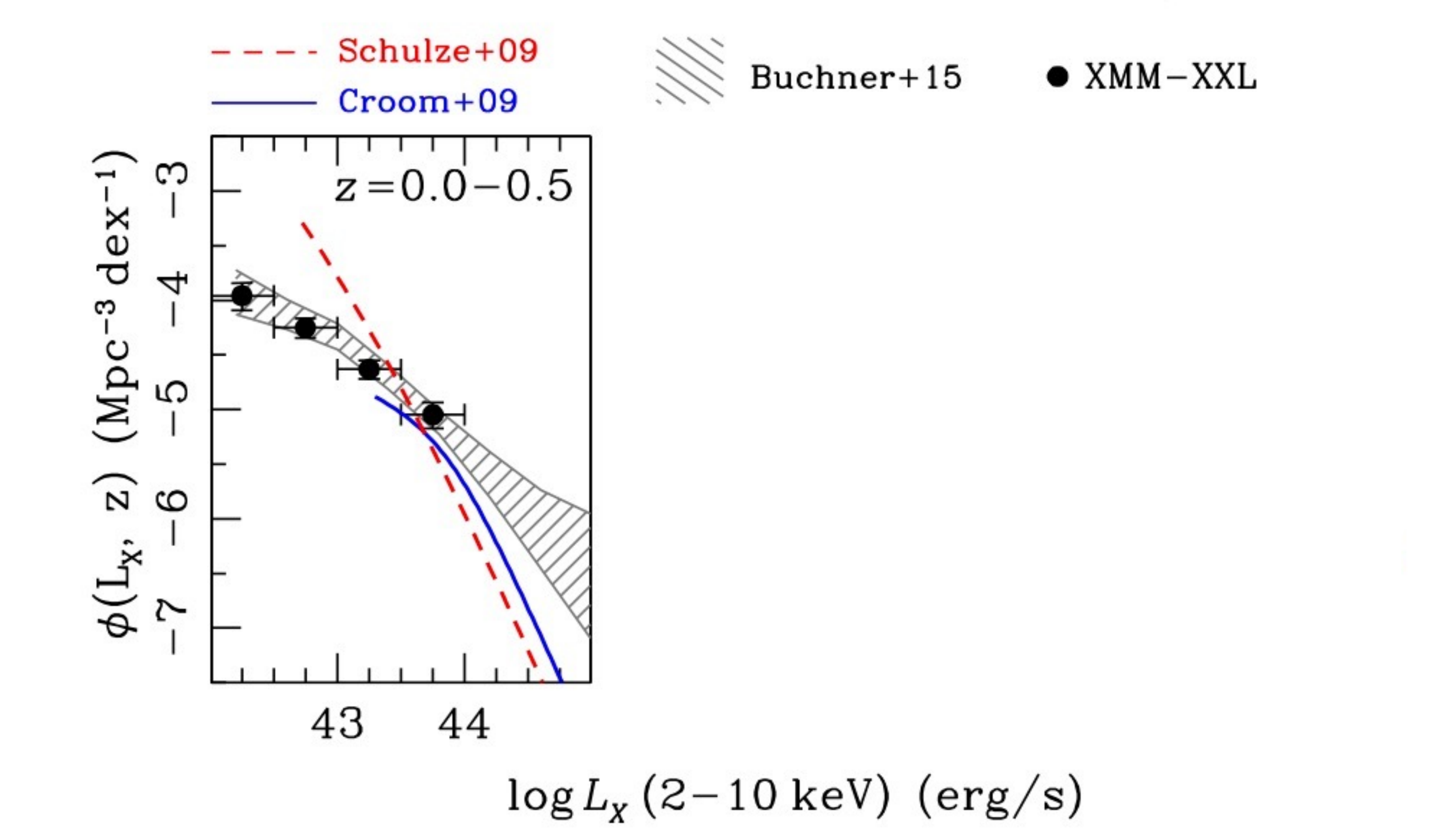


AGN WERE MORE LUMINOUS AND MORE NUMEROUS IN THE PAST

Now we can derive the LF with unprecedented detail as function of obscuration having numbers (~100,000) far exceeding the optical LF NUMBERS, SDSS/2QZ (Croom+09) based on 10,000 QSOs ($0.4<z<2.2$)

One major issue is that the optical and X-ray LF do not appear to evolve in the same way
Pure Luminosity Evolution vs Luminosity Dependent Density Evolution

OPTICAL VS. X-RAY LUMINOSITY FUNCTION

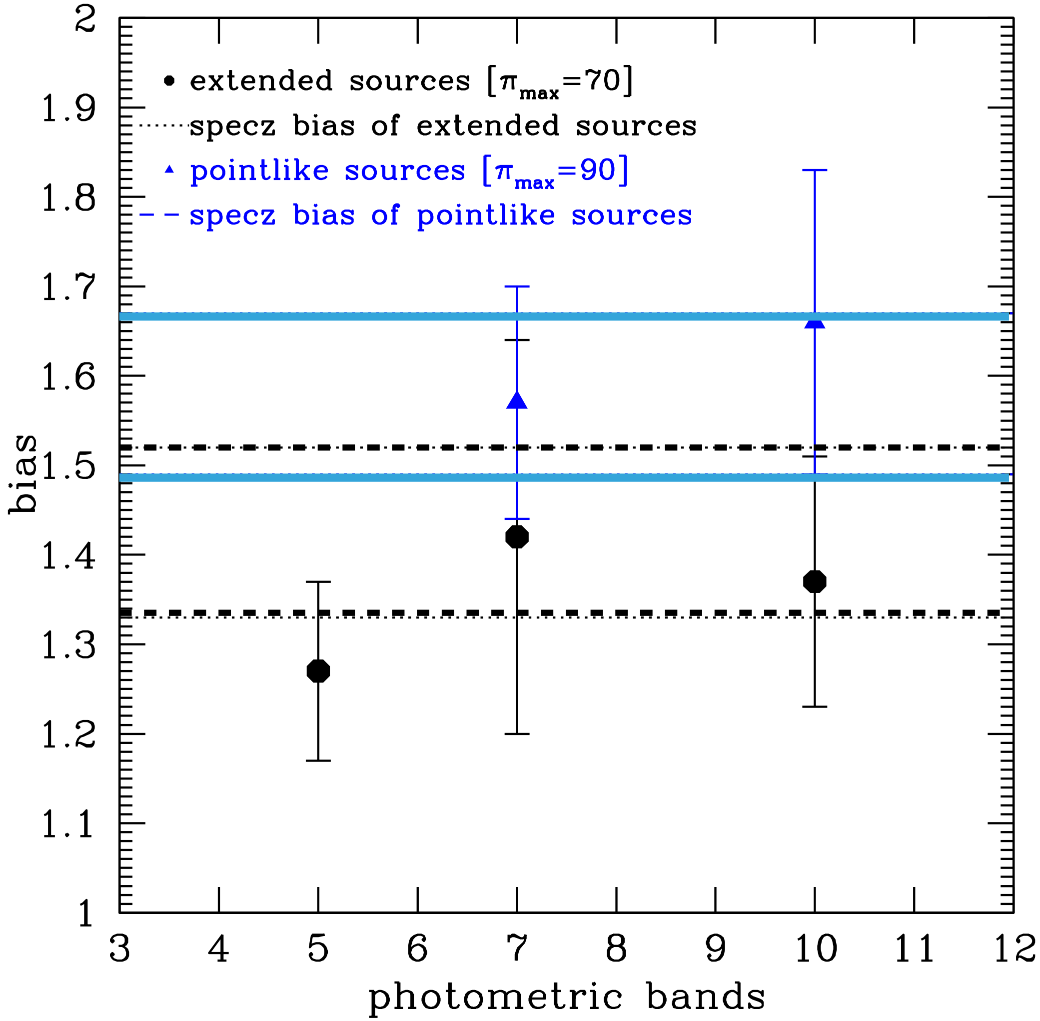


COMPARISON BETWEEN SPEC AND PHOT-Z IN THE XMM/XXL NORTH

Points: 300 phot-z sources

Horizontal lines: same 300 sources, spec-z

(1- σ uncertainty)



http://xraygroup.astro.noa.gr/Webpage-prodex/

+ 3XMM WEB-PAGE IN IRAP

Mountrichas et al. 2017, A&A , 608, A39, for the application of TPZ in the XMM-ATLAS survey

Ruiz et al. A&A, submitted