IDENTIFICATIONS OF X-RAY SOURCES

Lessons from COSMOS and CDFS (among others) and perspectives for eROSITA

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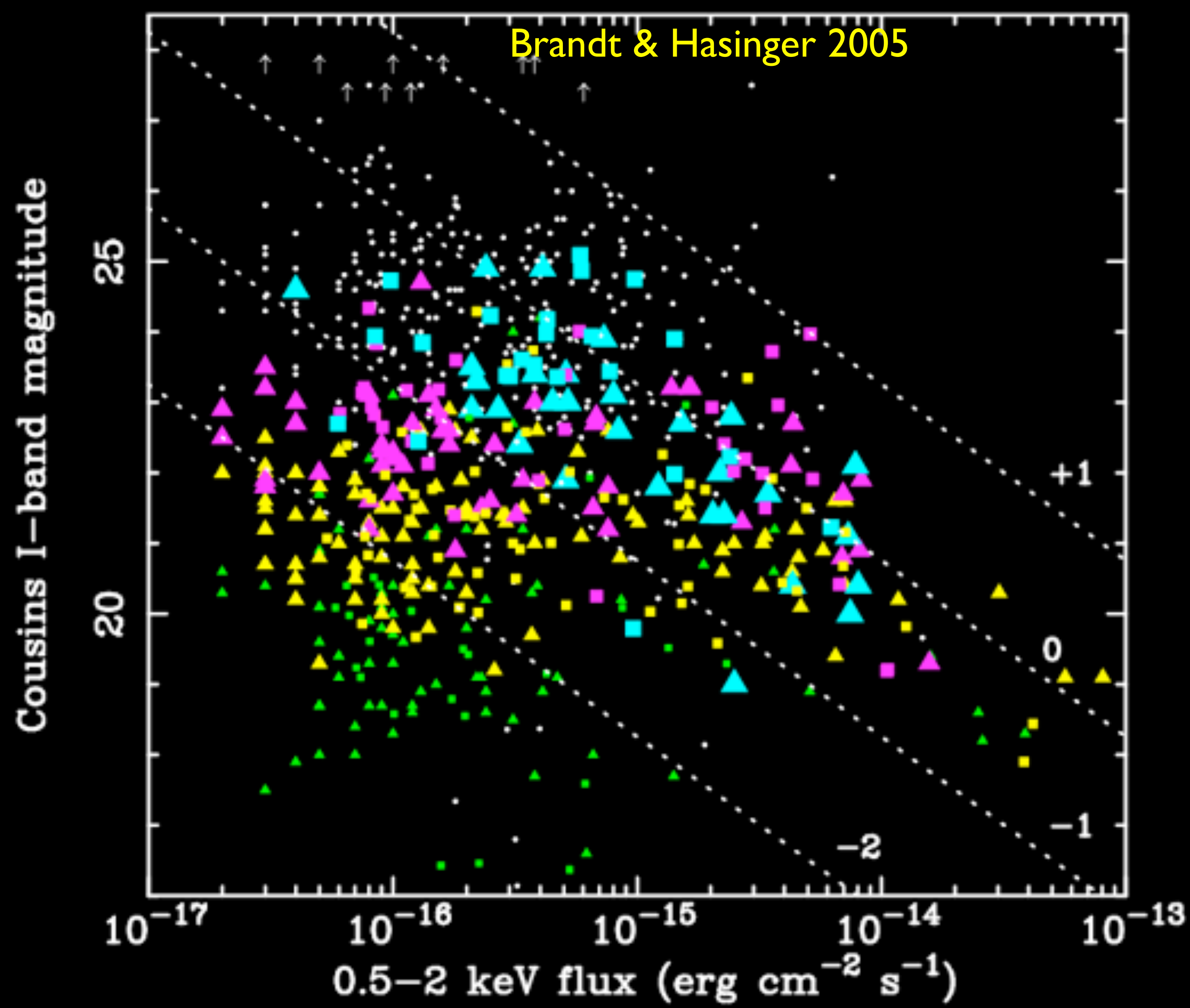
First International eROSITA conference,
17-20 October 2011
Garmisch-Partenkirchen

Identification of AGN in X-ray surveys

Fact:

counterparts identifications first crucial step to do science with X-ray surveys



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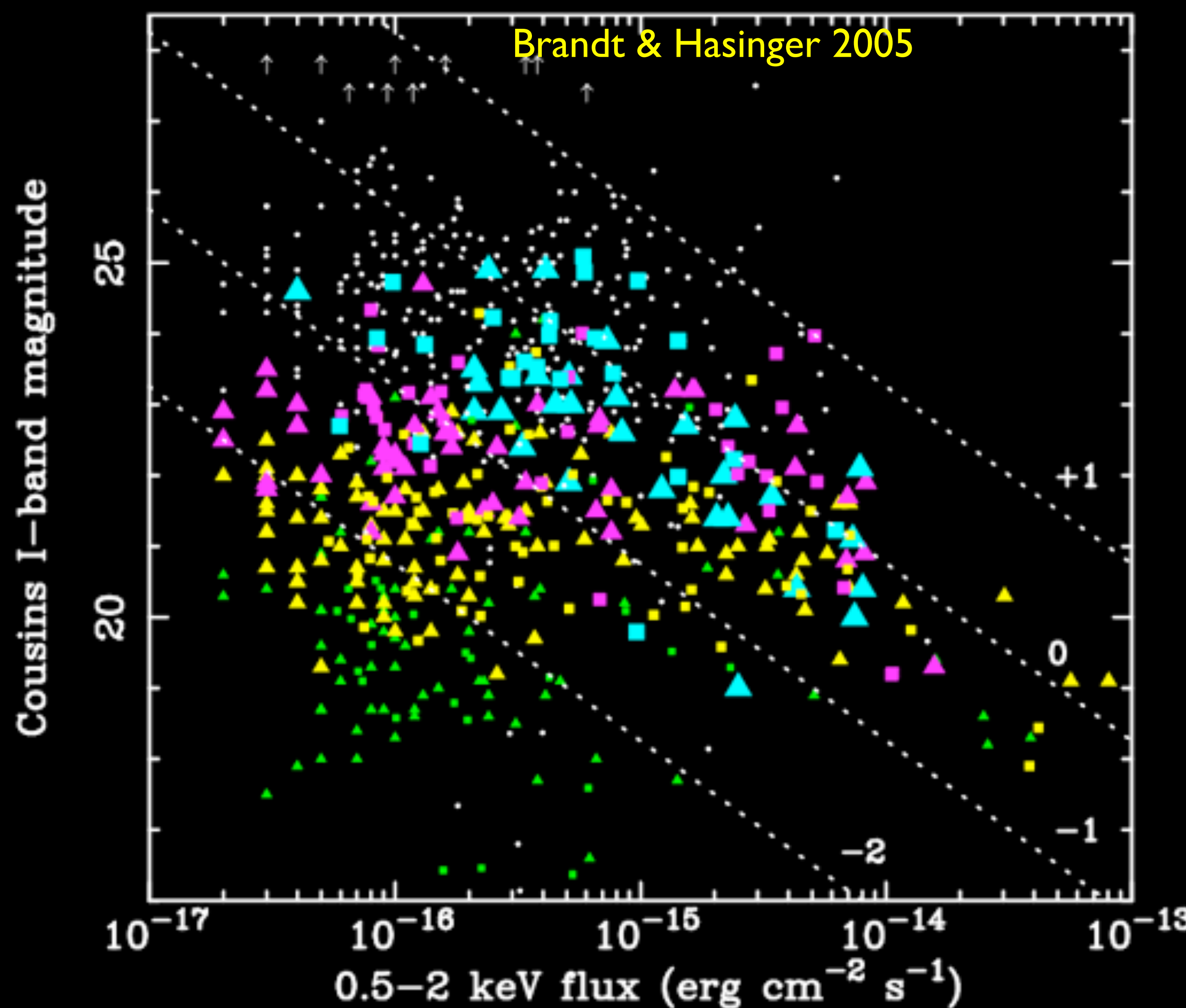
1) **optically faint (I>23)** sources difficult to identify using optical bands only
2) **large number of sources:** difficult to identify by eyeball inspection



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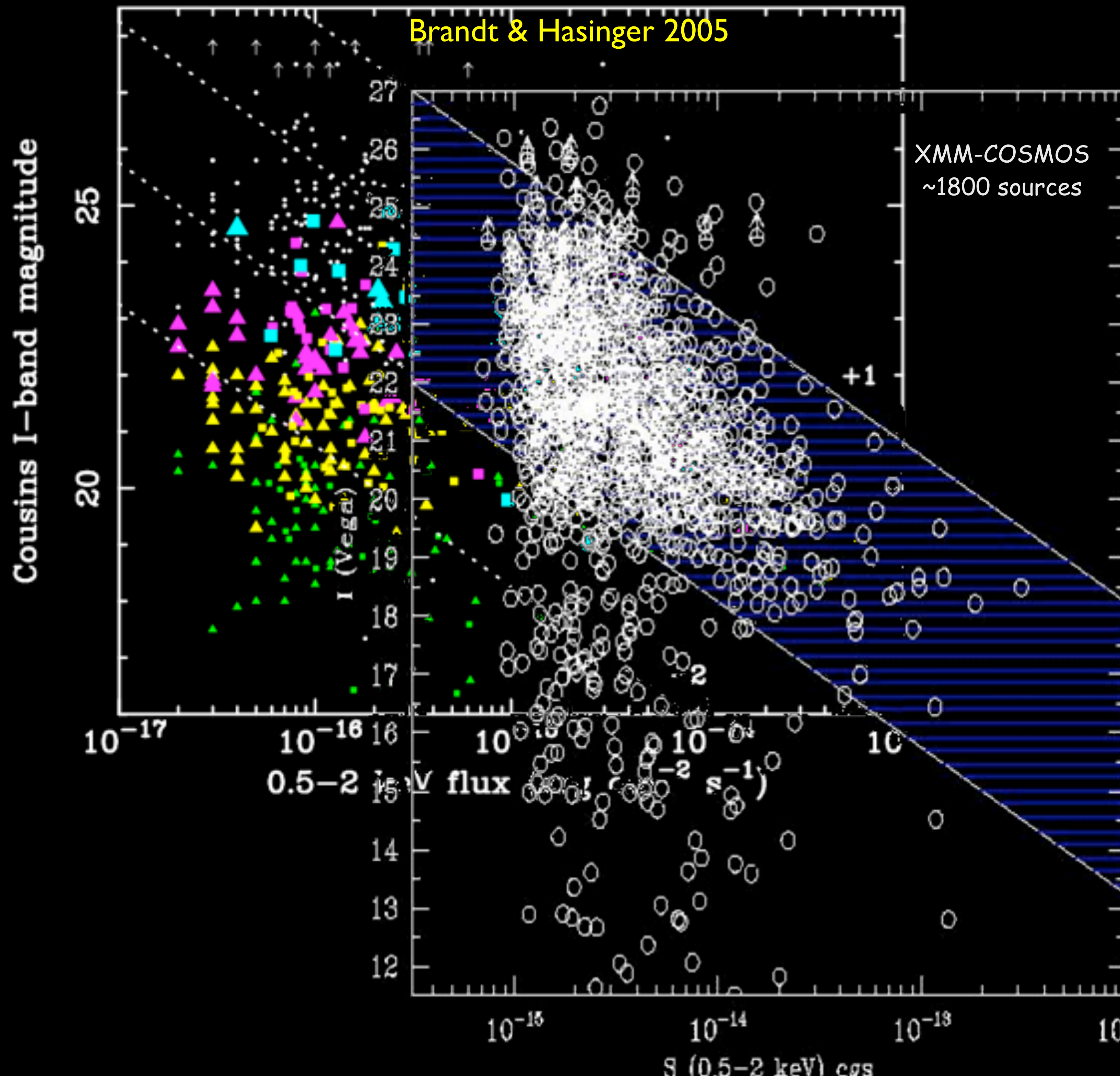

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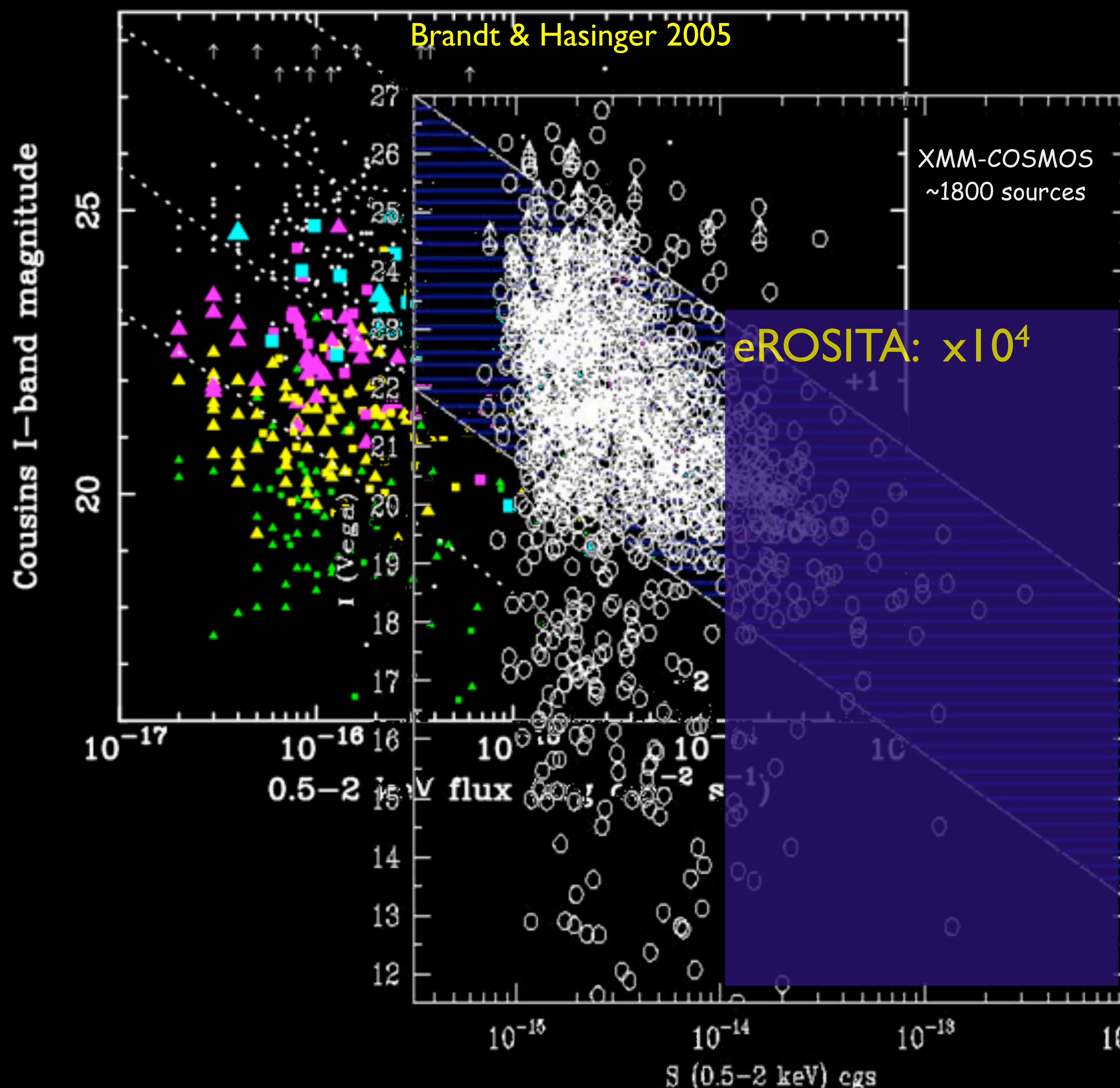

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1) **optically faint (I>23)** sources difficult to identify using optical bands only
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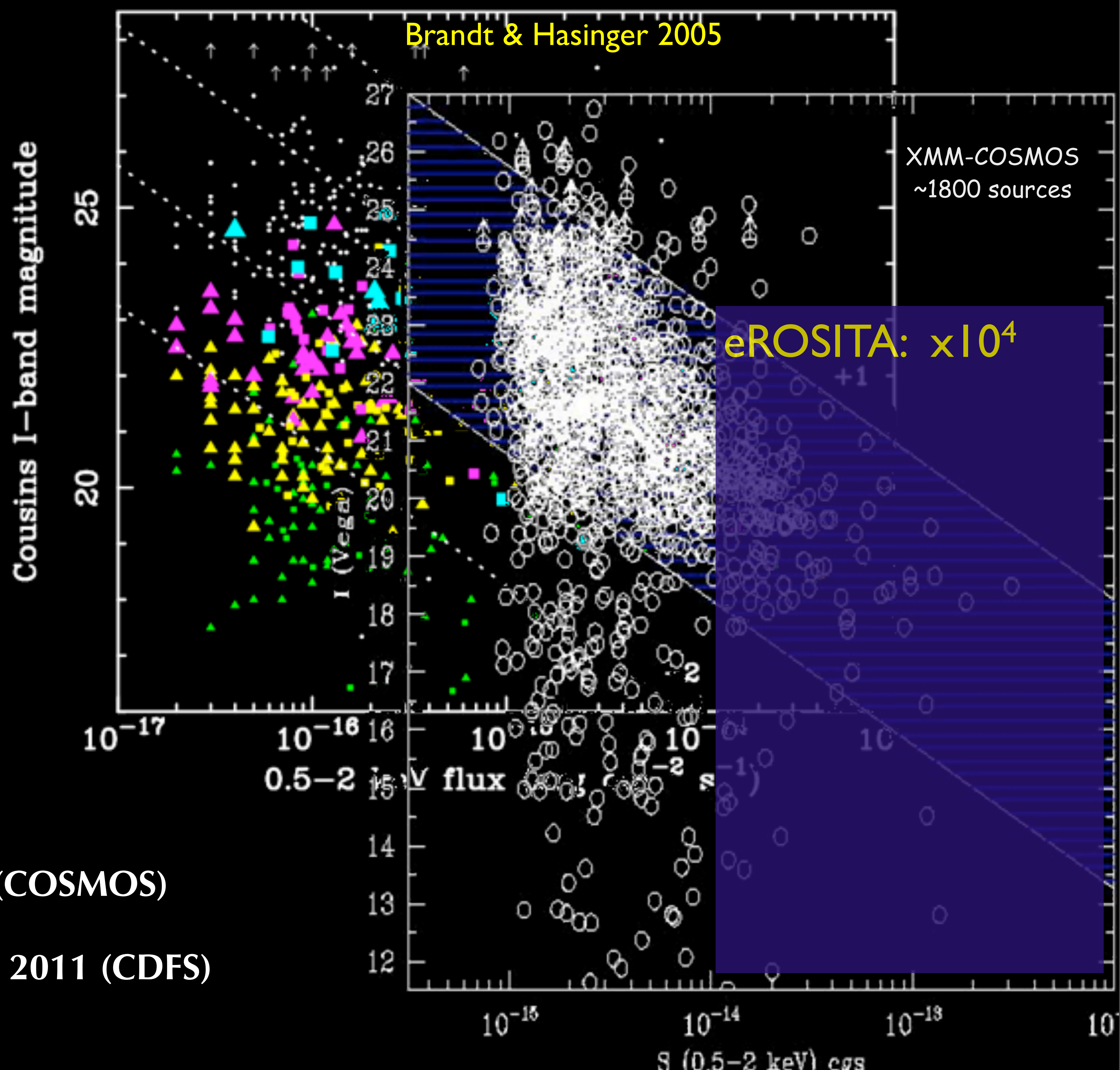
Solutions:
Importance of mw (NIR) coverage:
Alexander et al. 2001, Brusa et al. 2003, Mignoli et al. 2004, Mainieri et al. 2005 [incomplete list]
Statistical association methods:
Brusa et al. 2005
Brusa et al. 2007, 2010, Civano et al. 2011 (COSMOS)
Laird et al. 2009 (AEGIS)
Brusa et al. 2009, Luo et al. 2010, Xue et al. 2011 (CDFS)
Pineau et al. 2011 (2XMM)
Georgakakis & Nandra 2011 (XMM-SDSS) [incomplete list]



Counterparts Identifications (1)

(some references: Sutherland & Saunders 1992, Ciliegi et al. 2003, Brusa et al. 2005)

1) a statistical, powerful, method, the "Likelihood Ratio Technique" (Sutherland & Sanders 1992)

2) combined information from different wavebands (optical / K-band / IR)

$$LR=f(r)*q(m)/n(m)$$

- f(r) = distance term
- n(m) = background galaxies
- q(m) = overdensities of the counterparts

LR is computed for ***each*** source in ***each*** band (I,K,3.6micron..)

Output: for each band, the most likely counterpart ("unique"); in case of >=2 equally likely counterparts (in the same and/or from different bands) all the cp are considered ("ambiguous")

Important for **XMM sources** (at almost all fluxes) and Chandra sources mostly at $F<10^{-15}$

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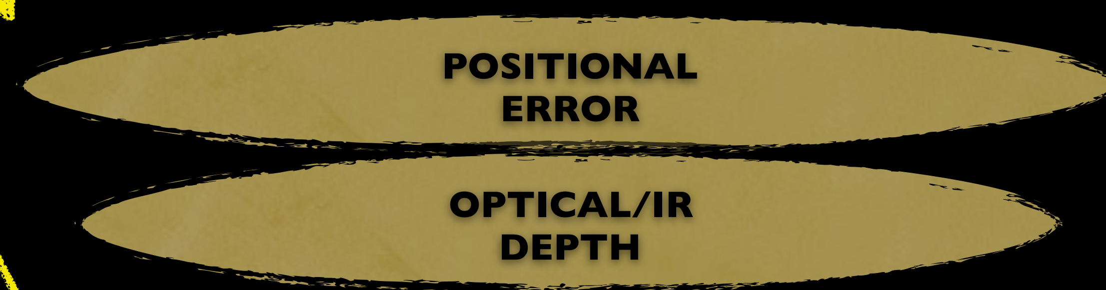

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Counterparts Identifications (2)

XMM-COSMOS (see Brusa et al. 2010)

Keywords: "bright" fluxes, deep and mw data, "large" positional errors

BREAKDOWN:

81% unique associations; **18%** ambiguous, **1%** not identified at **Fx>10^{-15}**

TABLE 1
SUMMARY OF OPTICAL IDENTIFICATION OF POINT-LIKE XMM SOURCES

sample	Total sources	Reliable (%)	Ambiguous (%)	unidentified (%)
*Chandra*area (before *Chandra*check)	850	712 (83.8%)	135 (15.9%)	3 (0.3%)
*Chandra*area (after *Chandra*check)	850	829 (97.5%)	21 (2.5%)	0 (0.%)
XMM-COSMOS area (before *Chandra*check)	1797	1457 (81%)	319 (18%)	21 (1.0%)
XMM-COSMOS area (after *Chandra*check)	1797	1577 (87.7%)	203 (11.3%)	17 (1.0%)
XMM-COSMOS area (after flux thresholds)	1651	1465 (88.7%)	175 (10.6%)	11 (0.7%)

RELIABILITY of the method ["a posteriori" test on XMM-COSMOS id using Chandra]

98.7% [only 9/712 unique sources resulted associated to the wrong optical cp]

LESSONS LEARNED:

method works **very well**

statistical properties of "primary" and "secondary" counterparts within ambiguous sources **indistinguishable**

Multiwavelength coverage needed to recover faint (<1e-14 cgs)

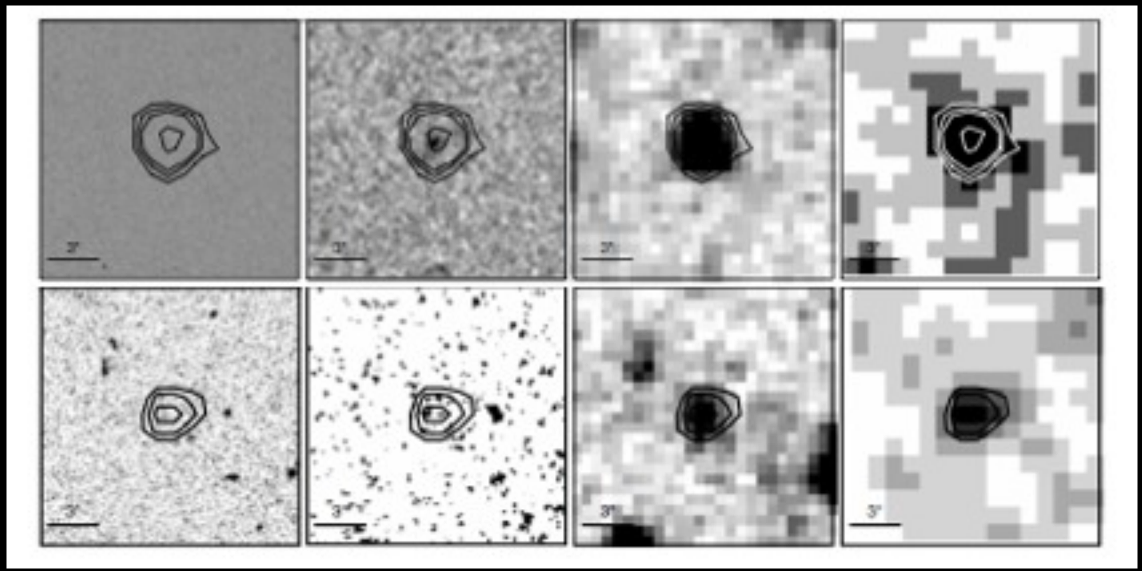
Counterparts Identifications (3)

C-COSMOS (see Civano et al. 2011, subm.)

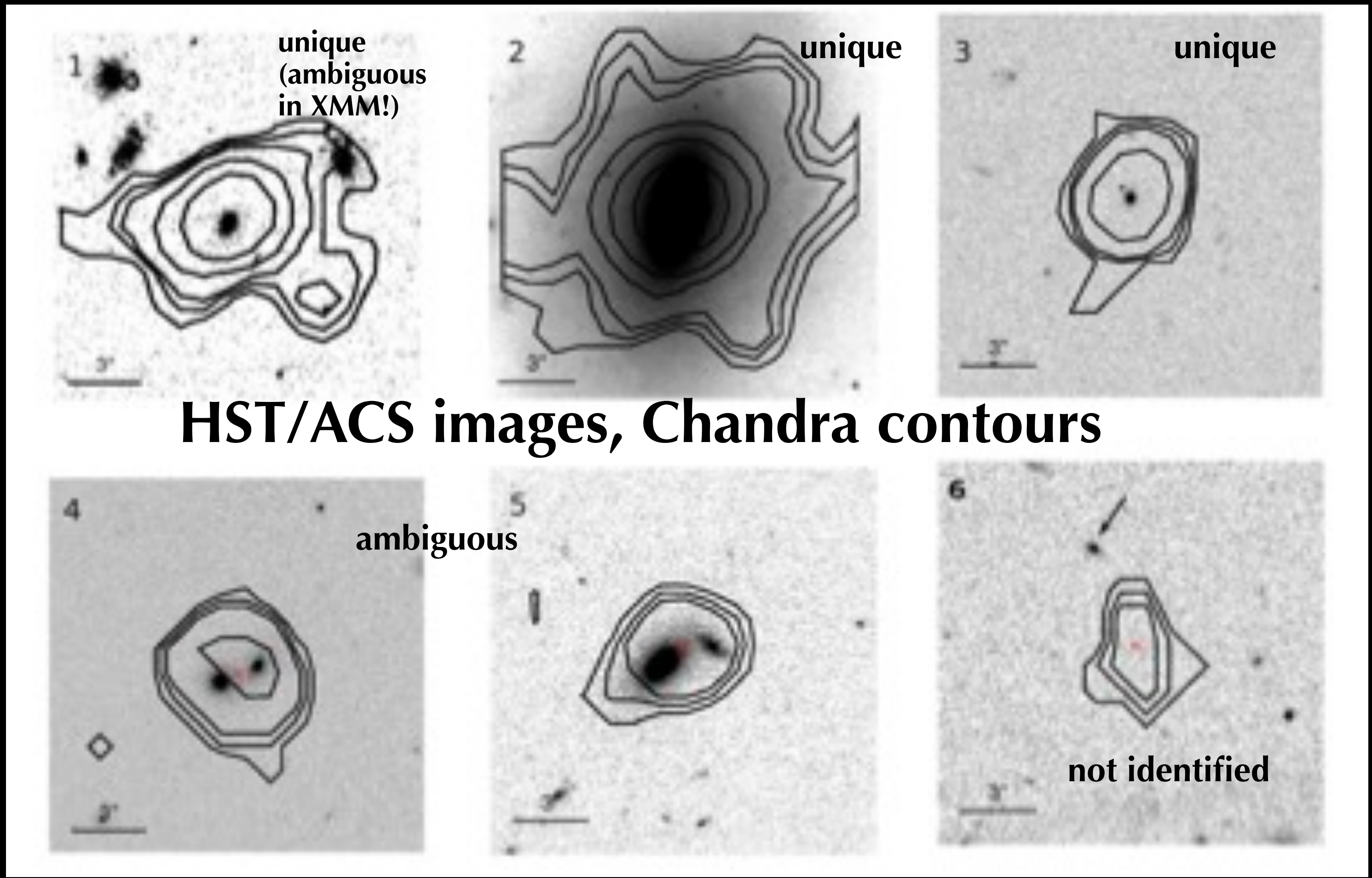
Keywords: "faint" fluxes, deep and mw data, "small" positional errors

BREAKDOWN:

96.4% unique associations, **2%** ambiguous, **1.6%** not identified at **$F_x > 2 \times 10^{-16}$**



optical dropouts, only in K-IRAC



LESSONS LEARNED:

statistical properties of "primary" and "secondary" counterparts within ambiguous sources **indistinguishable**

match of X-ray and optical/NIR depths is very important

		K (1)	K (2)	*i* (1)	*i* (2)	3.6μm (1)	3.6μm (2)	Total %	Total Number
1	secure id.	90.1%	89.8%	84.8%	84.1%	95.6%	94.9%	96.4%	1697
2	ambiguous id.	2.7%	2.6%	5%	4.7%	1.3%	1%	2%	36
3	sub-threshold id.	4.2%	2.3%	9.2%	6.1%	1.8	3.8%	1.1%	19
4	unidentified	3.1%	3.5%	1%	2.1%	1.3	3.3%	0.5%	9
5	retrieved		1.8%		3%				

Counterparts Identifications (4)

CDFS (see Brusa et al. 2009, Luo et al. 2010, Xue et al. 2011)

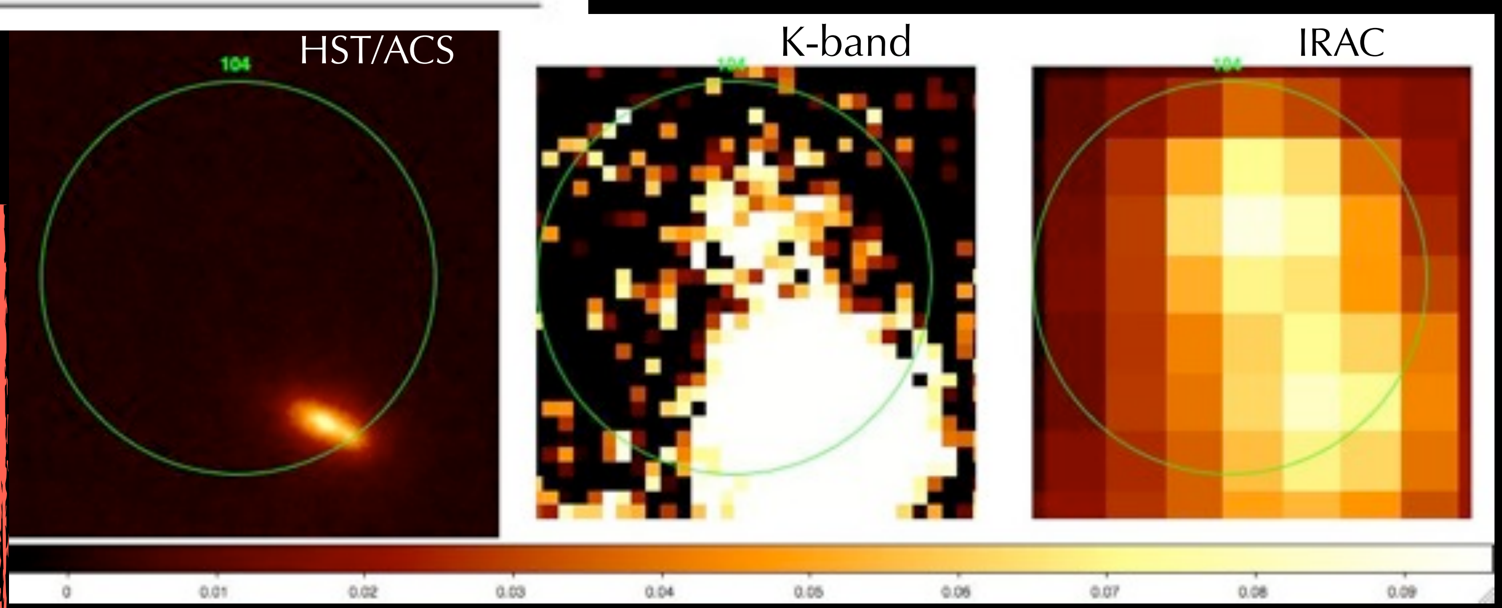
Keywords: "faintest" fluxes, deep and mw data, "small" positional errors

BREAKDOWN

86% unique associations, **10%** ambiguous, **4%** not identified at fluxes **Fx>4x10^{-17}**

Summary of the Likelihood-ratio Matching Parameters and Results

Catalog (1)	Det. Thresh (2)	Depth (3)	Solid Angle (4)	N_o (5)	σ_o (6)	L_{th} (7)	R (8)	C (9)	N_X (10)	N_{ID} (11)	N_{NoID} (12)	N_{Multi} (13)	N_{False} (14)	False % (15)	Recovery % (16)	X–O % (17)	N_{Pri} (18)
WFI *R*	2σ	27.3	1420	30 345	0''1	0.55	0.97	0.73	462	344	118	2	32	9%	67.5%	1.0%	19
GOODS-S *z*	0.6σ	28.2	160	33 955	0''1	0.80	0.93	0.82	311	259	52	8	23	9%	75.9%	0.7%	220
GEMS *z*	1.7σ	27.3	830	22 016	0''1	2.35	0.97	0.67	462	312	150	5	14	4%	64.5%	1.4%	89
MUSIC *K*	1σ	23.8	140	13 595	0''1	1.30	0.93	0.84	262	223	39	4	8	4%	82.1%	1.6%	14
MUSYC *K*	23.5/arcsec^2	22.4	970	6998	0''2	0.85	0.99	0.70	462	326	136	0	12	4%	68.0%	4.5%	9
SIMPLE 3.6 μm	2σ	23.8	1640	22 095	0''3	0.20	0.99	0.89	462	414	48	0	32	8%	82.7%	1.7%	12
VLA 1.4 GHz	5σ	19.9	1170	338	0''1	2.25	0.99	0.20	462	94	368	0	0.5	1%	20.2%	27.7%	83



LESSONS LEARNED:

statistical properties of "primary" and "secondary" counterparts within ambiguous sources are **different** (different SEDs)

multiwavelength coverage **essential** to provide best identifications

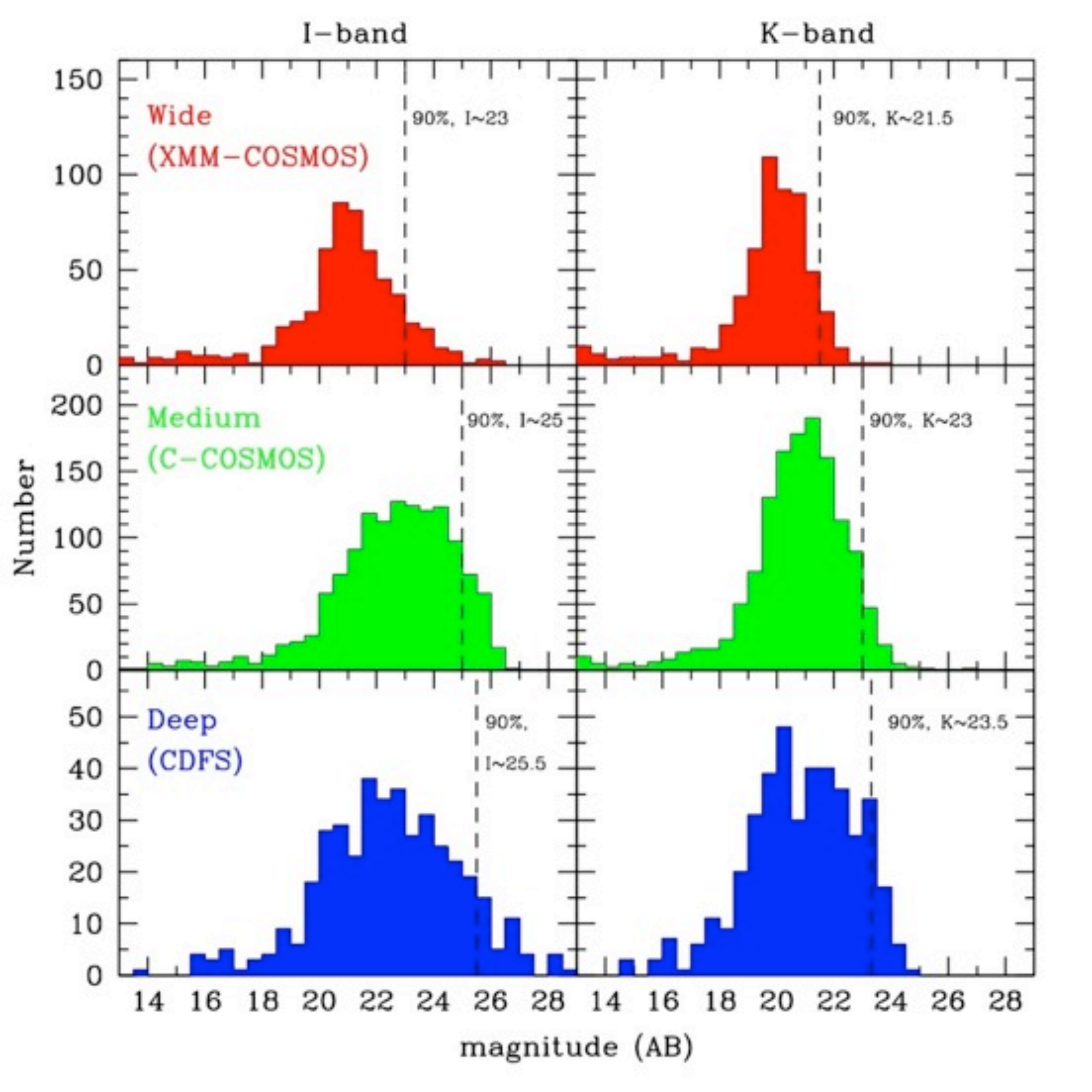
Depth of optical / infrared images: from what we know to what we need

[Brusa et al. 2011,arXiv:1008.1914; WFXT book]

Fx>1x10^{-15}

Fx>2x10^{-16}

Fx>4ex10^{-17}



81% secure

same depth
fainter fluxes
smaller errors

95% secure

~same depth
same error
fainter fluxes

85% secure

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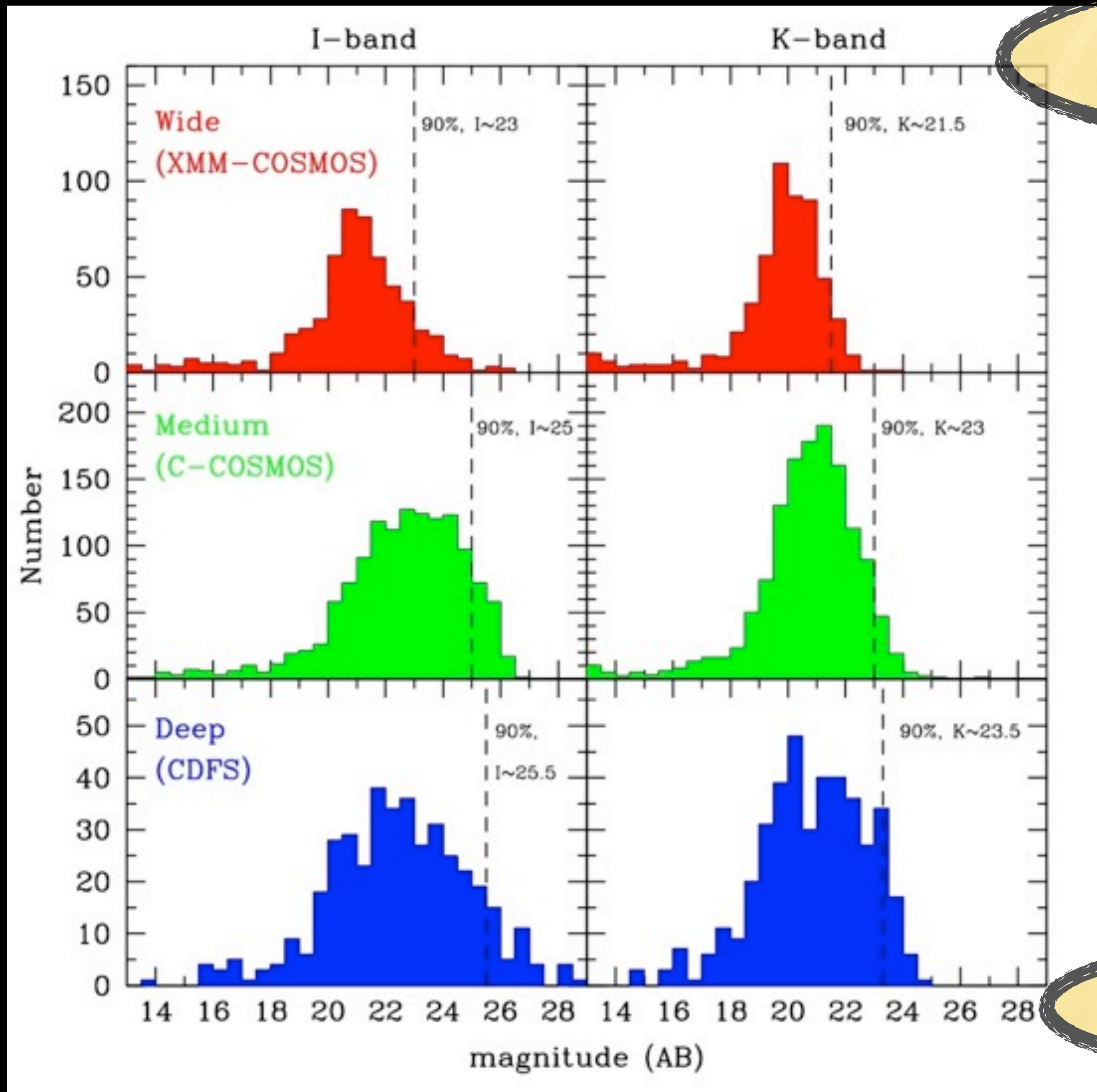

Main limitation: POSITIONAL ERROR

$Fx>1x10^{-15}$

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$Fx>2x10^{-16}$

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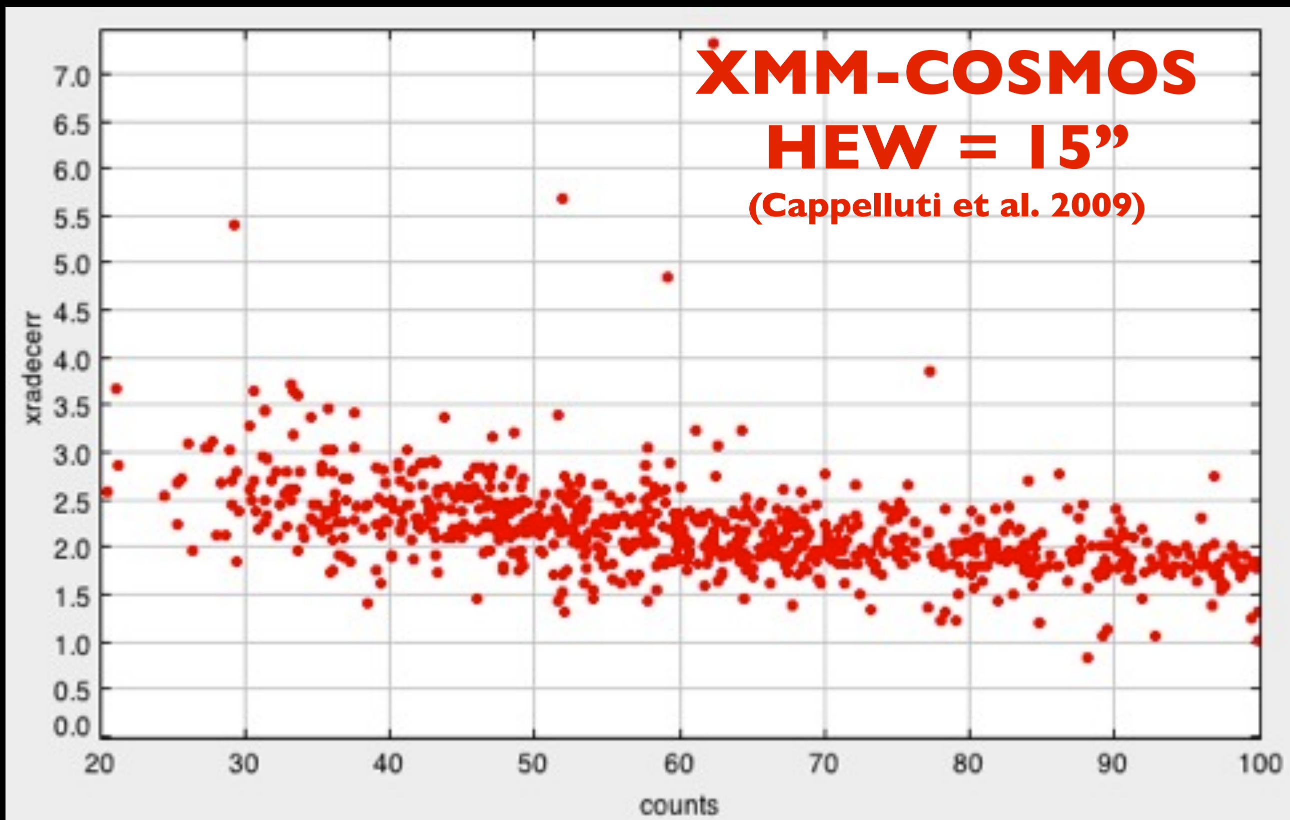
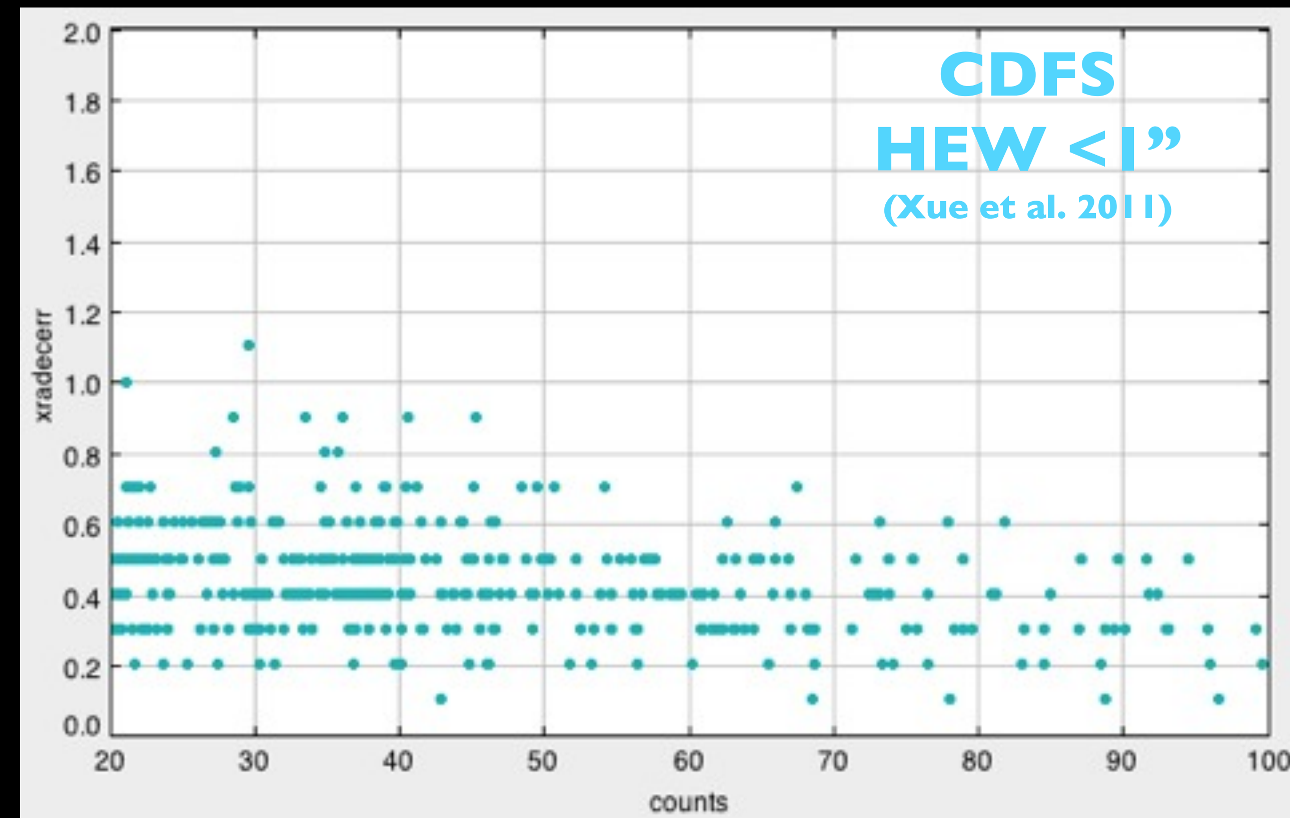
Main limitation: OPTICAL/IR DEPTH

eROSITA identifications (1): positional uncertainties ("larger")





XMM HEW of 15" --> positional accuracy between 1-3.5″

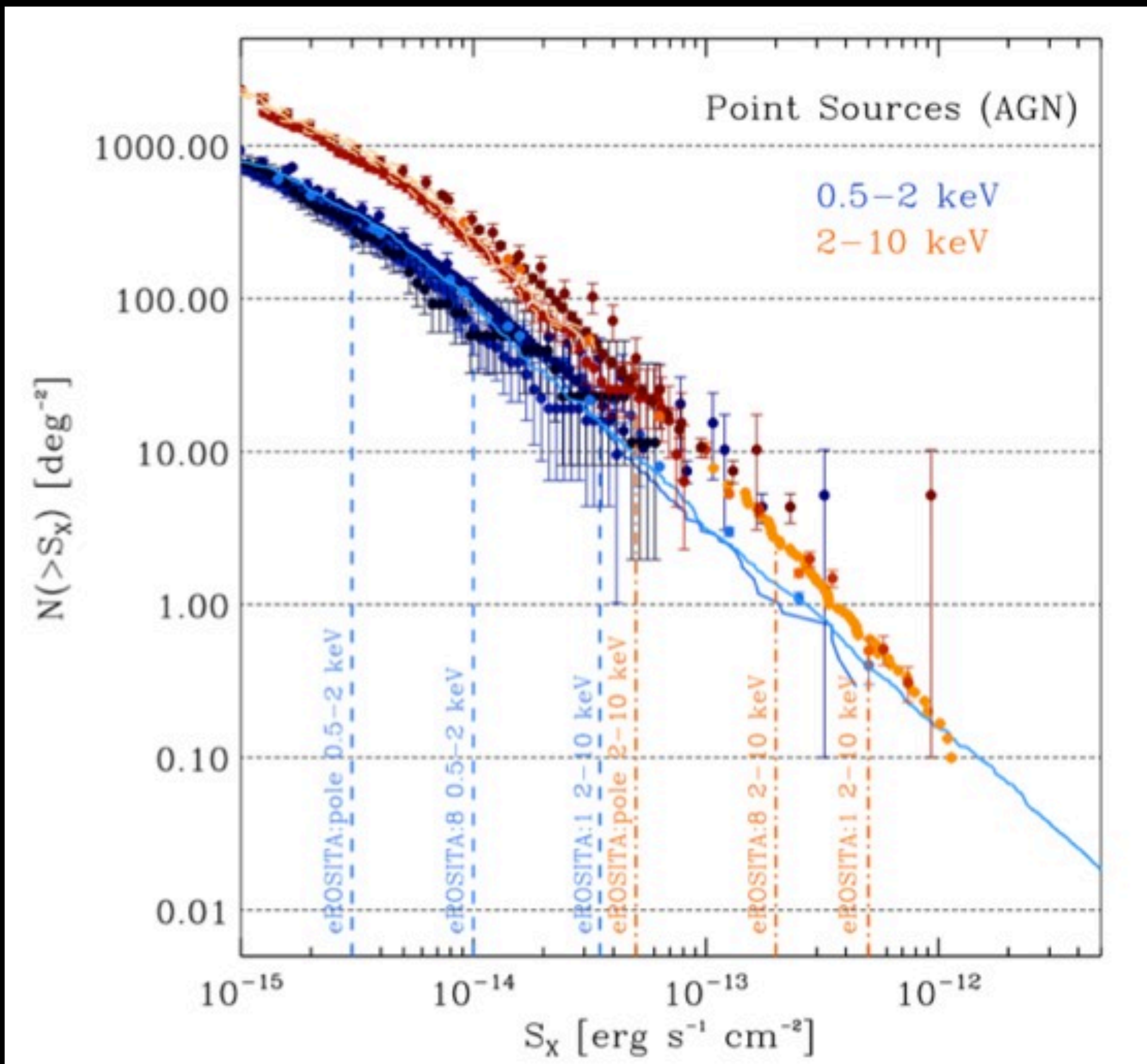
Chandra HEW of 2″ (averaged over FOV) --> positional accuracy between 0.2-1″

most eROSITA sources will have between 20 and 100 counts and averaged HEW ~25-30″

expected positional accuracies of the order of 3-5″ - need **simulations for quantitative estimates**

eROSITA identifications (2): fluxes ("brighter")

[From eROSITA White Book document]



see also Alex Kolodzig talk and Hermann Brunner poster

eRОSITA identifications (2): fluxes ("brighter")

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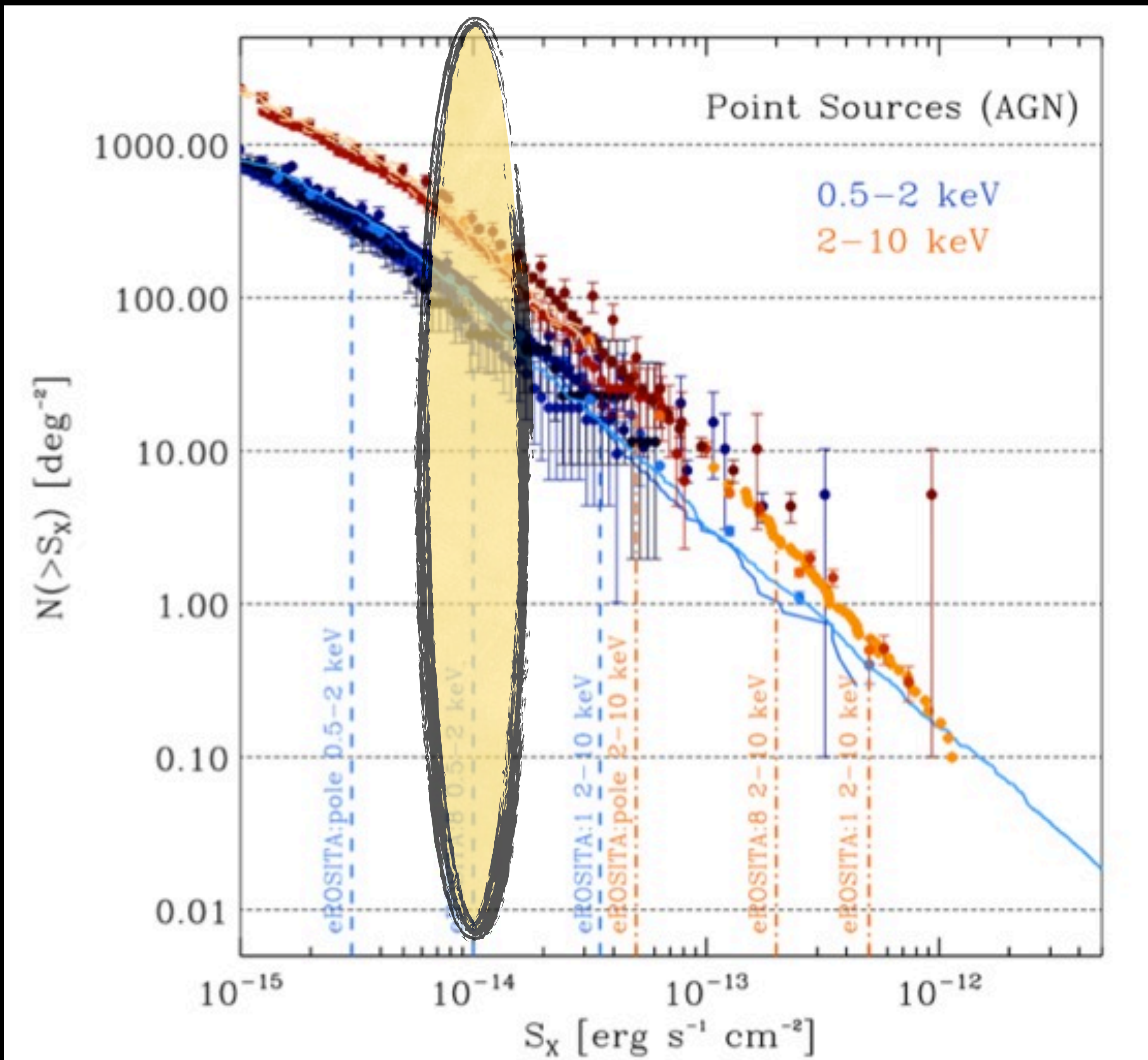


at the limiting flux of eROSITA all-sky (1×10^{-14}) XMM-surveys give:

~95% (Brusa et al. 2010)
based on the XMM-COSMOS

~85% (Georgakakis & Nandra 2011)
based on XMM/SDSS matches
[see also Pineau et al. 2011, 2XMM/SDSS]

differences are due to

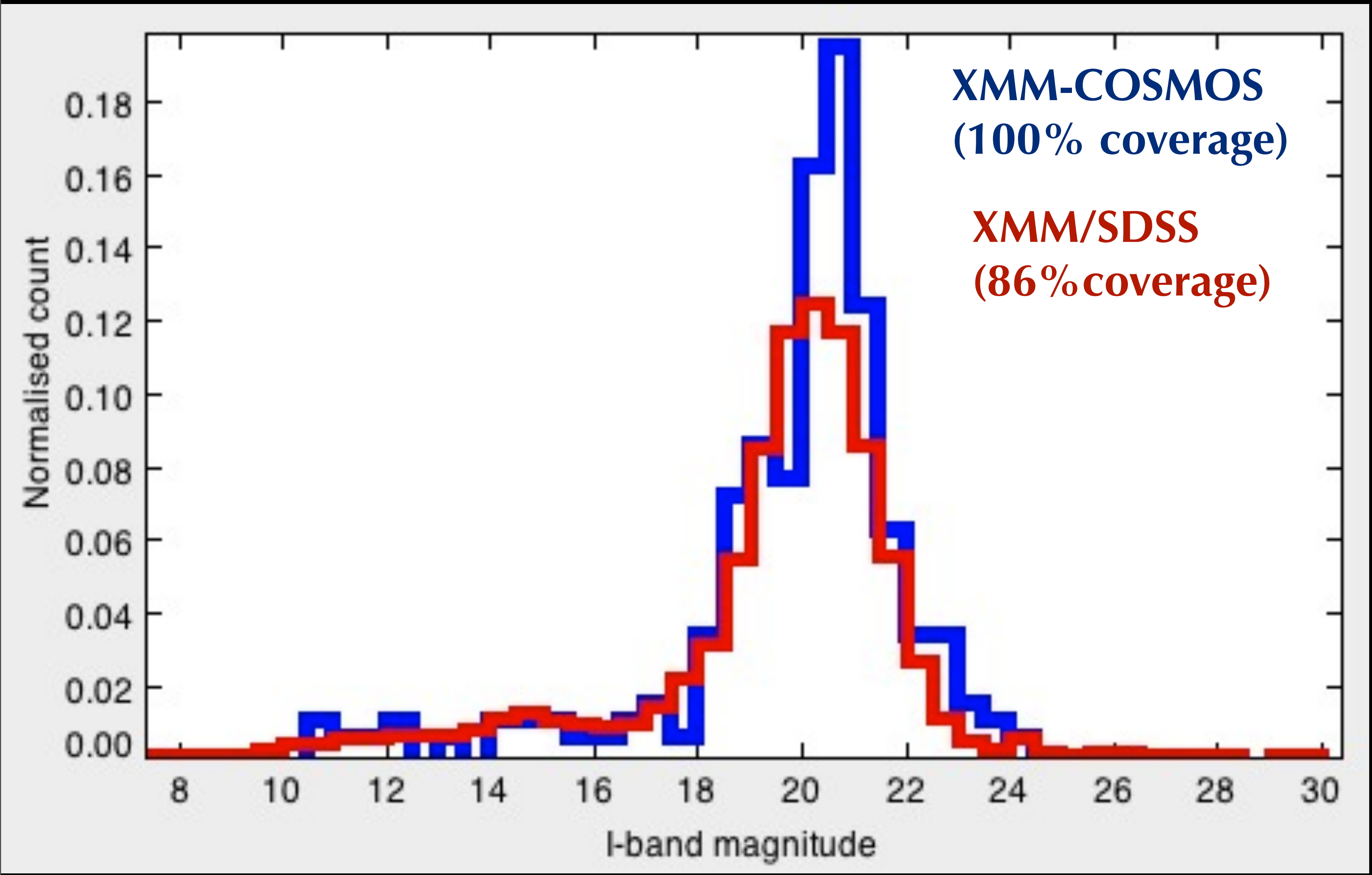
BANDS used and
DEPTHS available

real numbers for eROSITA maybe smaller (larger positional uncertainties)

see also Alex Kolodzig talk and Hermann Brunner poster

eROSITA identifications (3): magnitudes

(see session tomorrow!)



Optical resources [>5000 deg2] (existing and foreseen):

PanSTARRS1/2(all north):
I~22/24.5 (+grz)

DES (5000 deg2 south):
R~24 (rgizY)

Euclid (all sky):
r~24.5 (+ugrzy)

Spectrographs:
large FOV, large # fibers
SDSS-III (BOSS/Big-BOSS)
and beyond (**SPIDERS)**
4MOST (proposed @ESO)
see Axel Schwope talk

others not optical

VISTA/VHS: **K~20 (+HJY) (60-80% of the cp)**
EUCLID: **H~24 (+rYJ)**
WISE: **3.6~19.5 (not enough?)**
LOFAR: **0.8 mJy at 120 MHz (= 0.1 mJy at 1.4 GHz) "radio" emitters**

MAIN LESSON:

multiwavelength coverage and **appropriate depth** is crucial to identify sources
(photoz, SED studies, selections issues etc. come later!)

LESSONS from XMM-COSMOS:

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LESSONS from C-COSMOS:

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eROSITA perspectives:

identifications completeness of the order of **~80-90%** **feasible** with samples down to I~24

“depths” effects can be tested with XXL / BCS surveys using DES and/or PanSTARRS data
“positional uncertainties” effect needs simulations to be quantified

coordination/collaborations with major large area surveys /projects **mandatory**