The XMM-Newton Serendipitous Survey

Mike Watson

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XMM-Newton
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Topics

- The XMM serendipitous sky survey
  - *2XMM catalogue & future catalogues*
  - basic characteristics
  - example science
- Comparison with planned surveys: do we need both?

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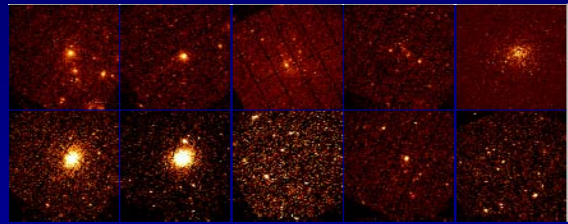
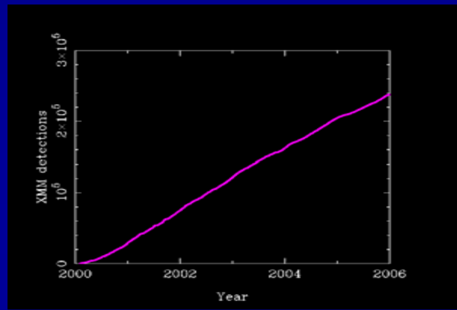
XMM-Newton Serendipitous Sky Survey



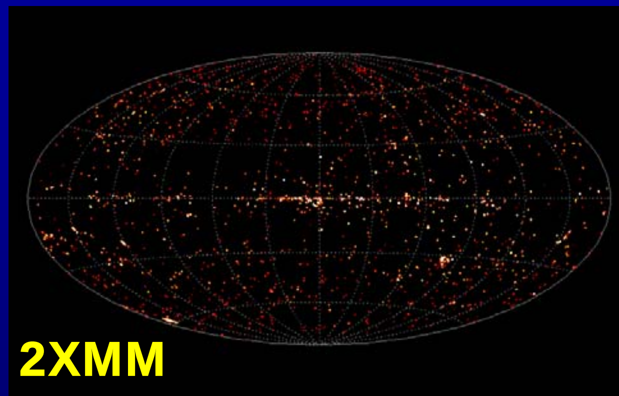
XMM pointed observation program

- 600-700 pointed observations per year
  - ⇒ sky coverage ~90 sq.deg/year
  - ⇒ 42K detections, 33K sources/year
  - ⇒ >600 sq.deg. to date
  - ⇒ $f_{x,min} < 10^{-14}$



XMM Catalogues

- constructed from whole pointed program by XMM-Newton Survey Science Centre on behalf of ESA
- 1XMM (2003), 2XMMp (2006), 2XMM (2007), *2XMMi (2008)*



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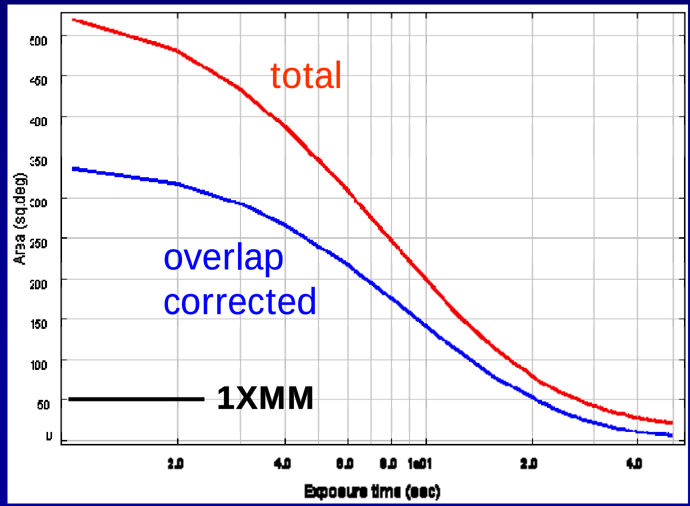
2XMM Catalogue

- **2XMM: largest X-ray catalogue ever**
  - 3491 XMM observations over ~6 years
  - 247K detections → 192K unique sources
  - 520 sq.deg. / 330 sq.deg. overlap excluded
  - "science grade" catalogue
    - state-of-the-art processing & instrument calibration
    - careful quality control, screening and characterisation
  - released August 2007

2XMM Sky Area



typically 40% overlap due to repeat pointings, mosaics etc.

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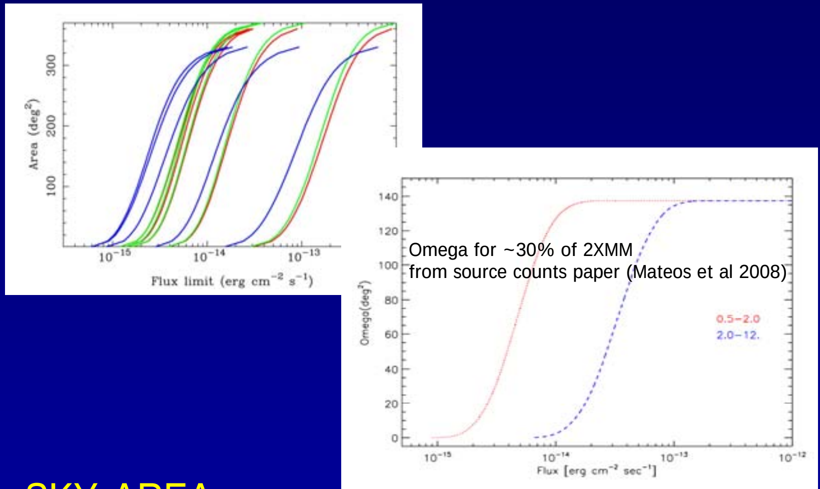
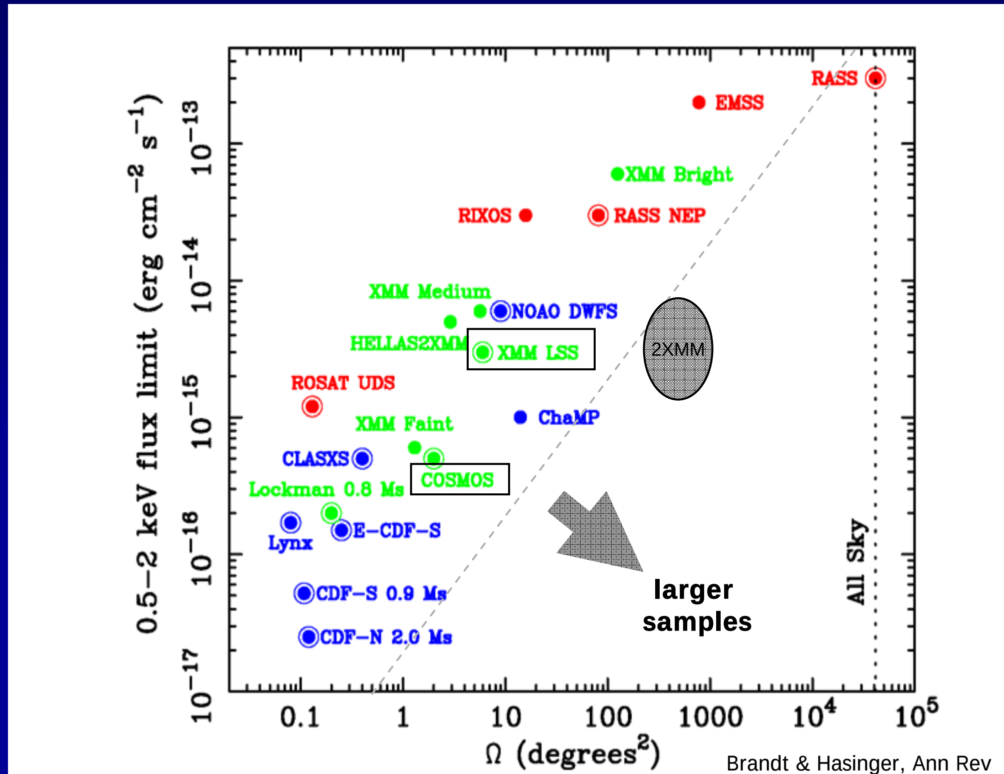




SKY AREA

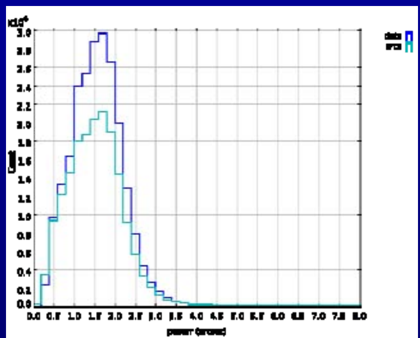
- 360 sq.deg. (MOS2); 320 sq.deg. (pn)

SENSITIVITY

typical (deepest) sensitivity limits

f_X (soft) ~ 3 (1) x 10^{-15}

f_X (hard) ~ 1.5 (0.8) x 10^{-14}



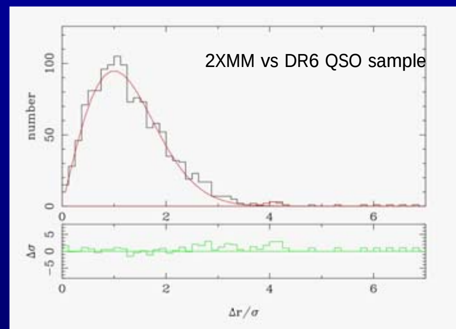
ASTROMETRY

position errors <σ> = 1.5 arcsec

➔ average position offset ≤2 arcsec

➔ max.position offset 5 arcsec (for vast majority)

➔ systematics (≤ 0.35") probably dominated by sampling/fitting



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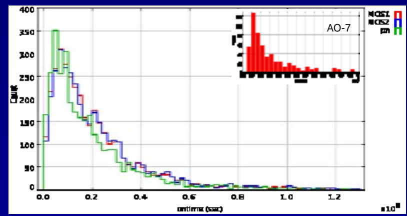
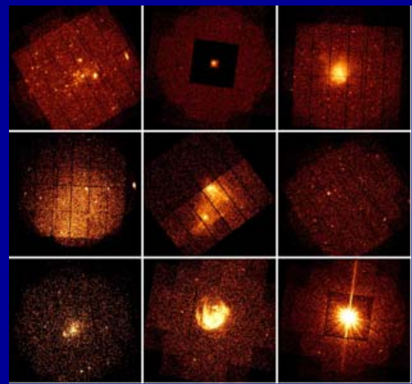
Key characteristics of XMM serendipitous sky survey

- Heterogeneous survey (by definition)
  - wide range of observation times
  - 65% at high b_{II}, 35% at low b_{II}
  - mixed observing modes/filters
- Image content/quality issues for survey science
  - bright point sources (PSF wings & OOT events)
  - bright extended sources
  - image defects
- Net effect for surveys
  - 30-70% useable fraction for serendipitous science: depending on project

observation time per field
(net science exposure)





2XMM source detection & characterisation
- 60% of obs. have <1% problem area
- 85% of obs. have <10% problem area

Field content: XMM targets
- 50% point-like
- 33% extended (10% <3')
- 15% "survey" (no discrete target)

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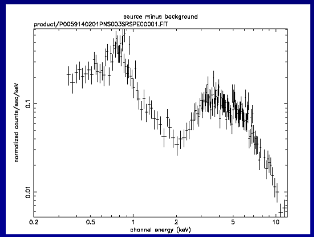
XMM Serendipitous Sky Survey

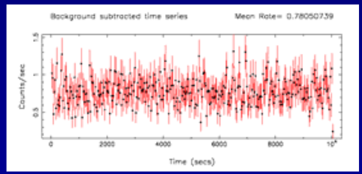
STRENGTHS

- observations free
- high quality catalogue & products publicly available
- very large sky area and sample size
  - 100 sq.deg. per year
  - 40K detections per year
  - cannot be matched by planned survey
  - large samples / rare objects
- useful depth for many projects
  - flux ~ bulk of CMXRB

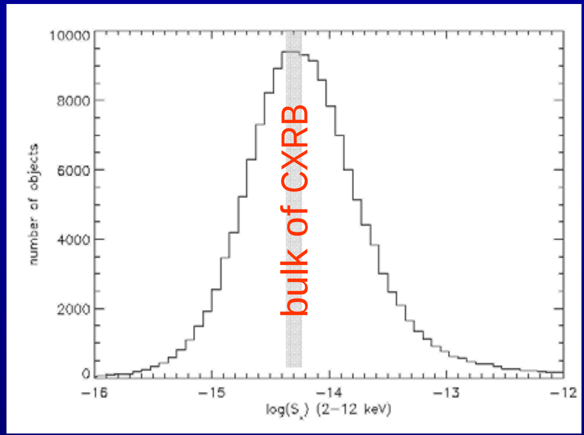
X-ray spectrum



time series



2XMM has spectra & time series for ~14% of all cat sources (~27K sources)



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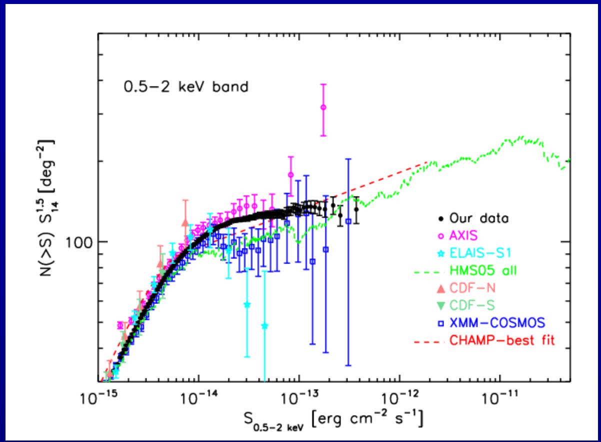
XMM Serendipitous Sky Survey:
High precision source counts

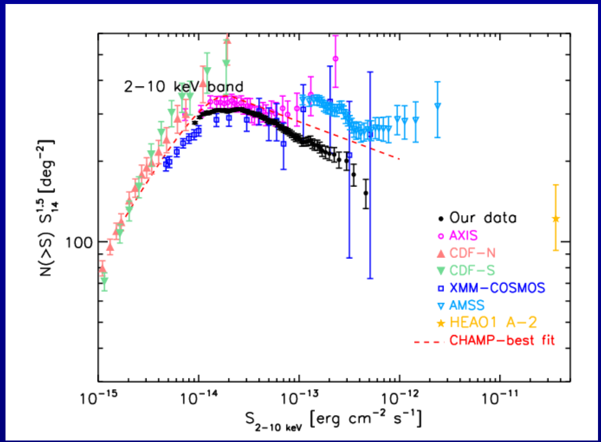
- 1129 XMM-*Newton* observations at |*b*| > 20°
- total sky area of 132.3 deg^2
- > 30,000 source detections
- best determination of extragalactic X-ray source counts
- immune from cosmic variance
- source counts in different bands provide **strong** constraints on distribution of AGN absorption [$N_H(L_x, z)$] via comparison with models

Mateos et al 2008

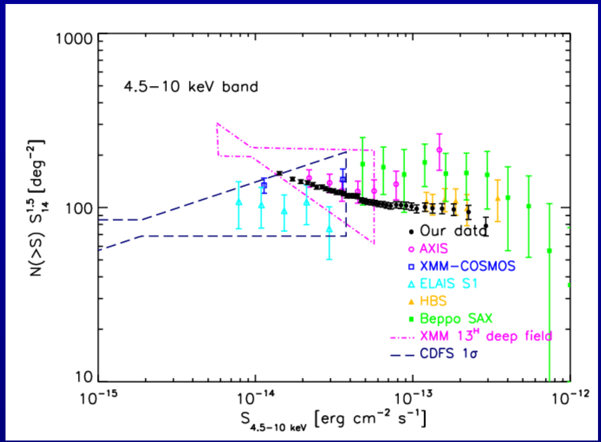
soft



hard



very hard



integral source counts: comparison with previous work

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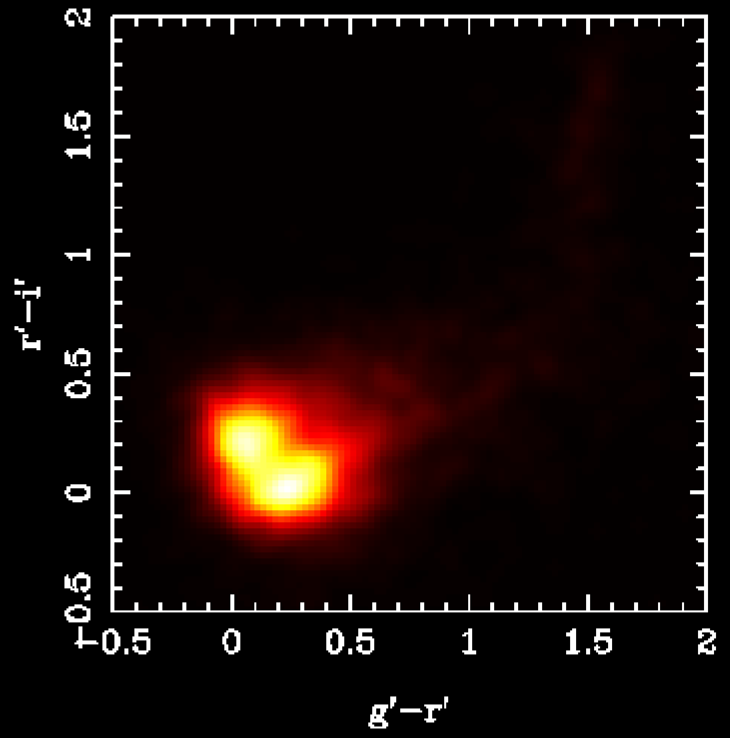
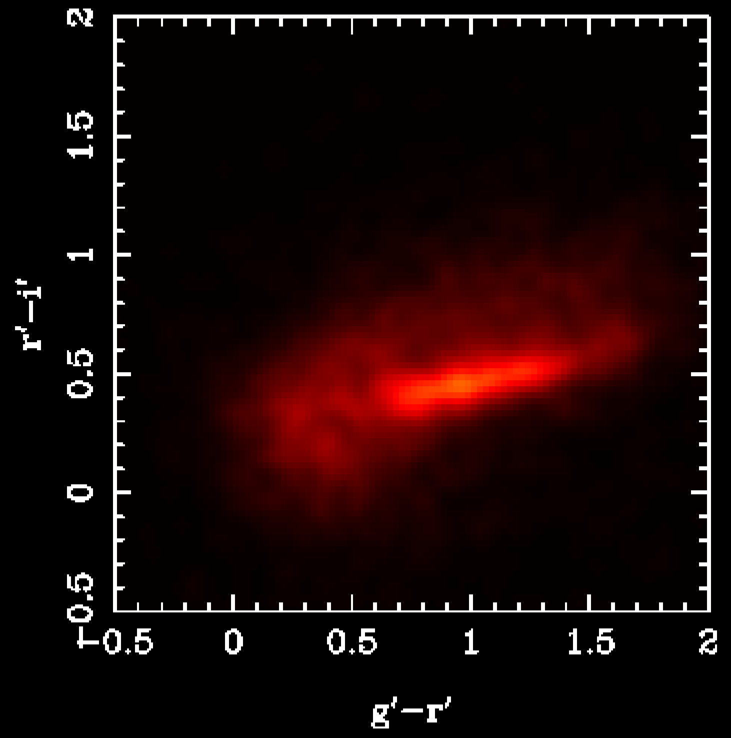
2XMM cross-match with SDSS DR5

Optical colour-colour plots for high fx / fopt

>10,000 sources
stellar: high fx / fopt



>10,000 sources
galaxy: high fx / fopt



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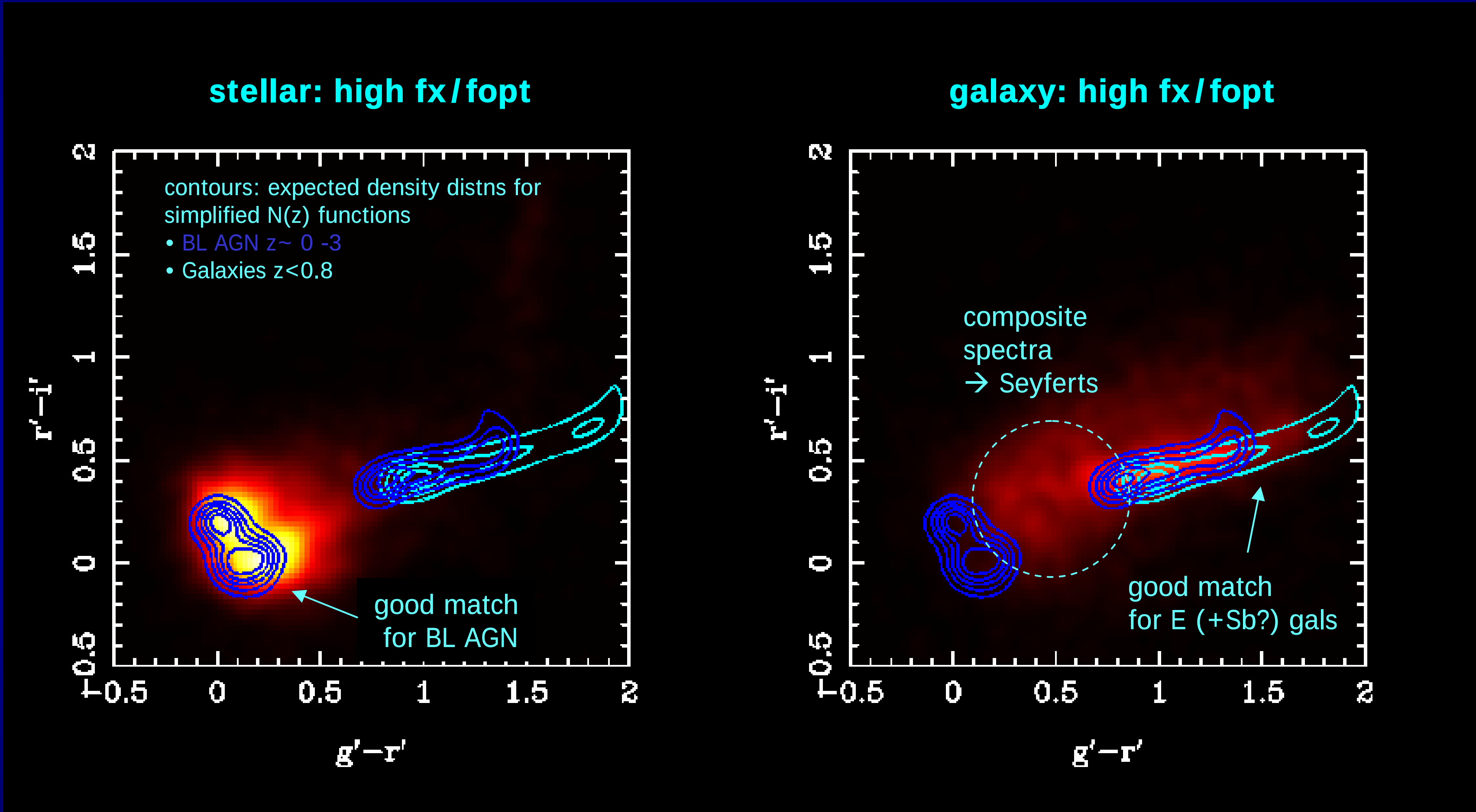
2XMM cross-match with SDSS DR5

Fit to observed distributions → constraints on N(z) for AGN population



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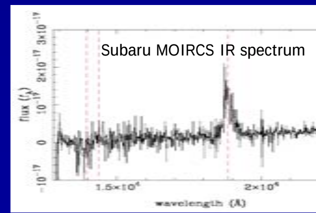
Extreme & rare objects in 2XMM

- AGN with f_x/f_{opt} (>3300)
  - highest recorded ratio, comparable to isolated NS
  - type 2 AGN @ z=1.87, host galaxy dominates up to K band
  - $L_X > 10^{46}$ erg cm^{-2} s^{-1}
  - massive host galaxy ~10^{11} $M_\odot$

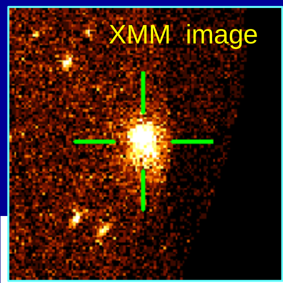
QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

SDSS i' NOT i' WFCAM J WFCAM K

Del Moro et al. (2008), submitted

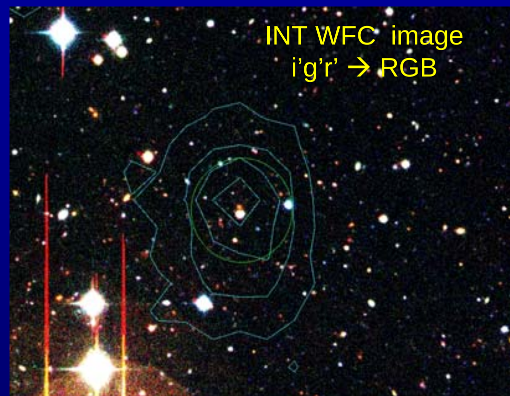


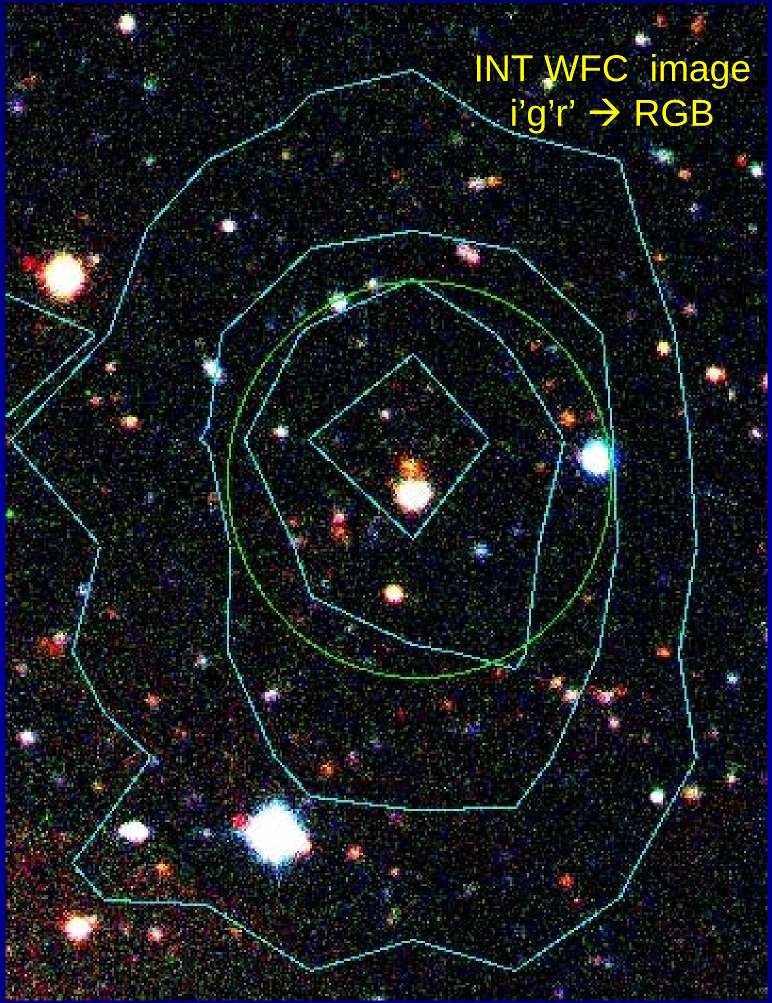
- Likely z>1 cluster of galaxies
  - no SDSS counterpart, no clear galaxy overdensity in deep INT imaging (griZ)
  - F_X = 3.5 x 10^{-13} cgs
  - for z >1, kT > 7 keV
  - $L_X > 5 \times 10^{44}$ erg s^{-1}

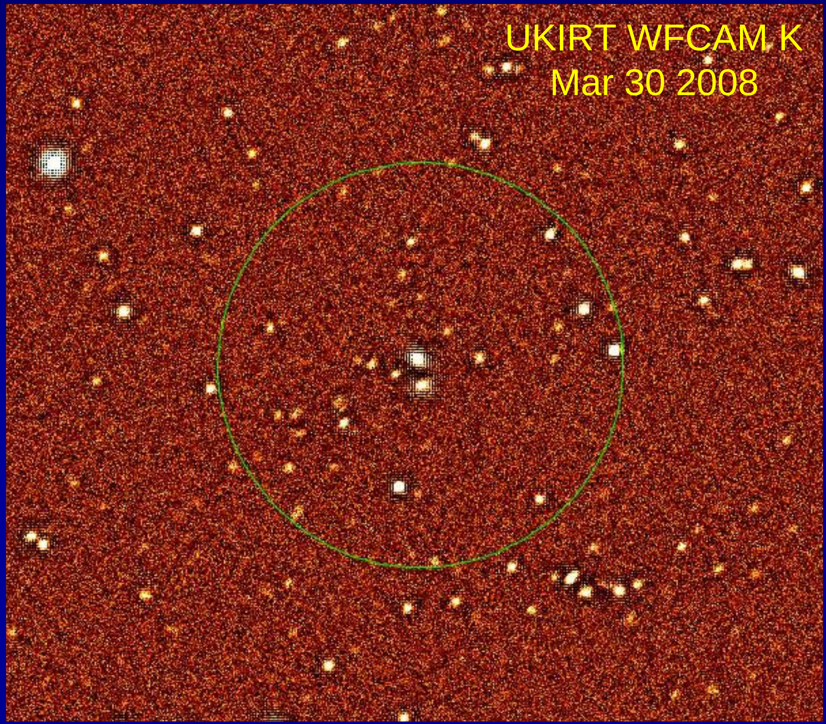


SDSS i' image

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.







Thanks to UKIRT service program and Mark Rawlings (JACH) for quick-look image

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XMM Serendipitous Sky Survey

ISSUES

- heterogeneous data: only ~30% useable for most demanding projects (efficiency issue)
- little area at deepest fluxes: eg <10% of total area at f_X(soft)~10^{-15}
- limited contiguous coverage (eg important for LSS)
- random sky distribution: λλ-data availability for ID and follow-up
  - **but** note all-sky and large area optical/IR surveys

  .... and existing follow-up programs

2XMM cross-match sample sizes

USNO B1:	35,000	
SDSS DR6:	30,000+	
2MASS:	23,000	
UKIDSS LAS :	7,000	(DR3)

UKIDSS/VISTA: 30-50% of XMM sky
PanStarrs: ~70% of XMM sky to 24^m

SSC XID program

ID of selected samples from XMM serendipitous surveys, eg XMS (Carrera et al.); XBS (Della Ceca et al.); GPS (Motch et al.)

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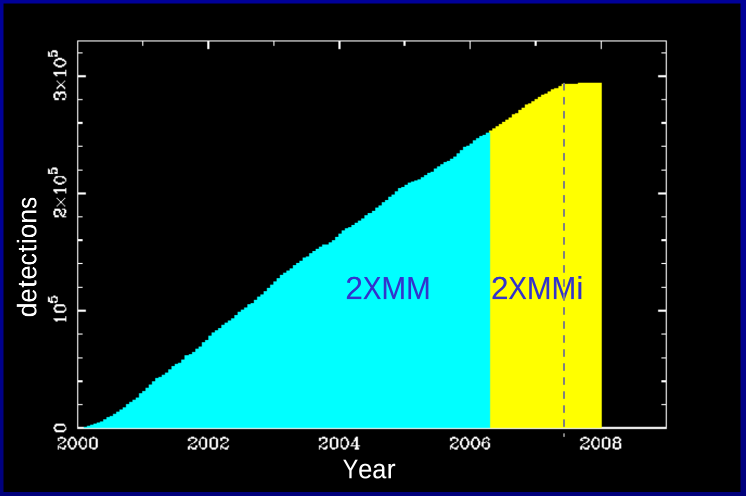
2XMMi (next installment of 2XMM)

- sources from additional year of XMM observations
  - public by May 2008, typically observed on or before April 2007
- ~700 extra observations
- new total catalogue size
  - detections: 300K (19% larger)
  - sources: 225K (17% larger)
- public release July/August 2008



Concluding remarks

- XMM serendipitous sky surveys & catalogues are invaluable FREE resource for characterising and exploring X-ray source populations
  - will continue to grow over lifetime of mission
- But serendipitous data does not meet all survey needs, in particular
  - contiguous/planned areas:
    - for effective follow-up/ID
    - LSS science
  - depth >20 ksec
  - uniformity, optimized mosaicing

- *New wide angle surveys with XMM would benefit significantly from a raster scan mode*

SPARE SLIDES

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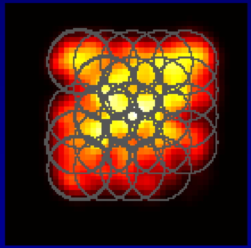
Planned vs serendipitous surveys

- Advantages of Planned (compared with Serendipitous) approach
  - uniformity
    - exposure, sensitivity, operating mode, filters...
  - desired depth (exposure time)
  - sky region
    - survey region can be chosen to avoid brightest point and diffuse sources
      - larger effective sky area for survey goal (factor ~2 or more)
    - survey region can be contiguous (required for some science goals)
    - **survey region can be chosen to match other resources (existing or planned), eg coverage at other λλ**
  - time variability: potentially available from repeated scans
  - → factor 3-10 more efficient than serendipitous data (for same area)

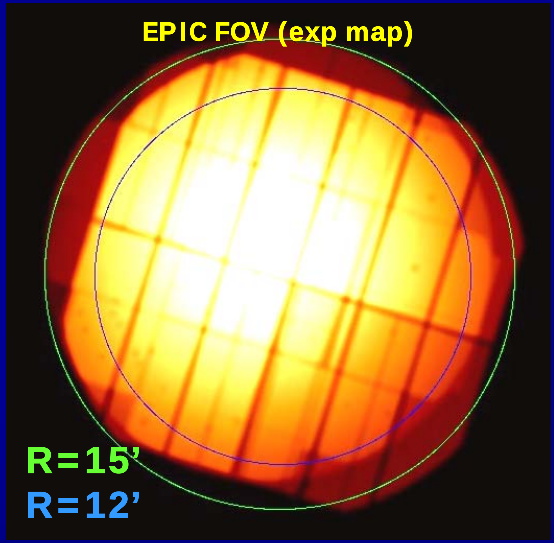
Survey strategies

How to map a region larger than XMM FOV with EPIC?

- Current approach
  - mosaic of overlapping pointings
  - overlap helps with
    - vignetting ←→ exposure map
    - PSF degradation off-axis
    - "edge" effects
- Issues
  - **observation overheads**
    - 3-6 ksec per pointing
  - exposure non-uniformity
  - effects of space weather
- FUTURE
  - larger areas?
  - deeper few sq.deg. surveys?



COSMOS (public data)



R_{FOV} ≈ 15 arcmin;
A_{FOV} ≈ 0.18 sq.deg. ≈ 700 sq.arcmin.
Best data inside R~12 arcmin

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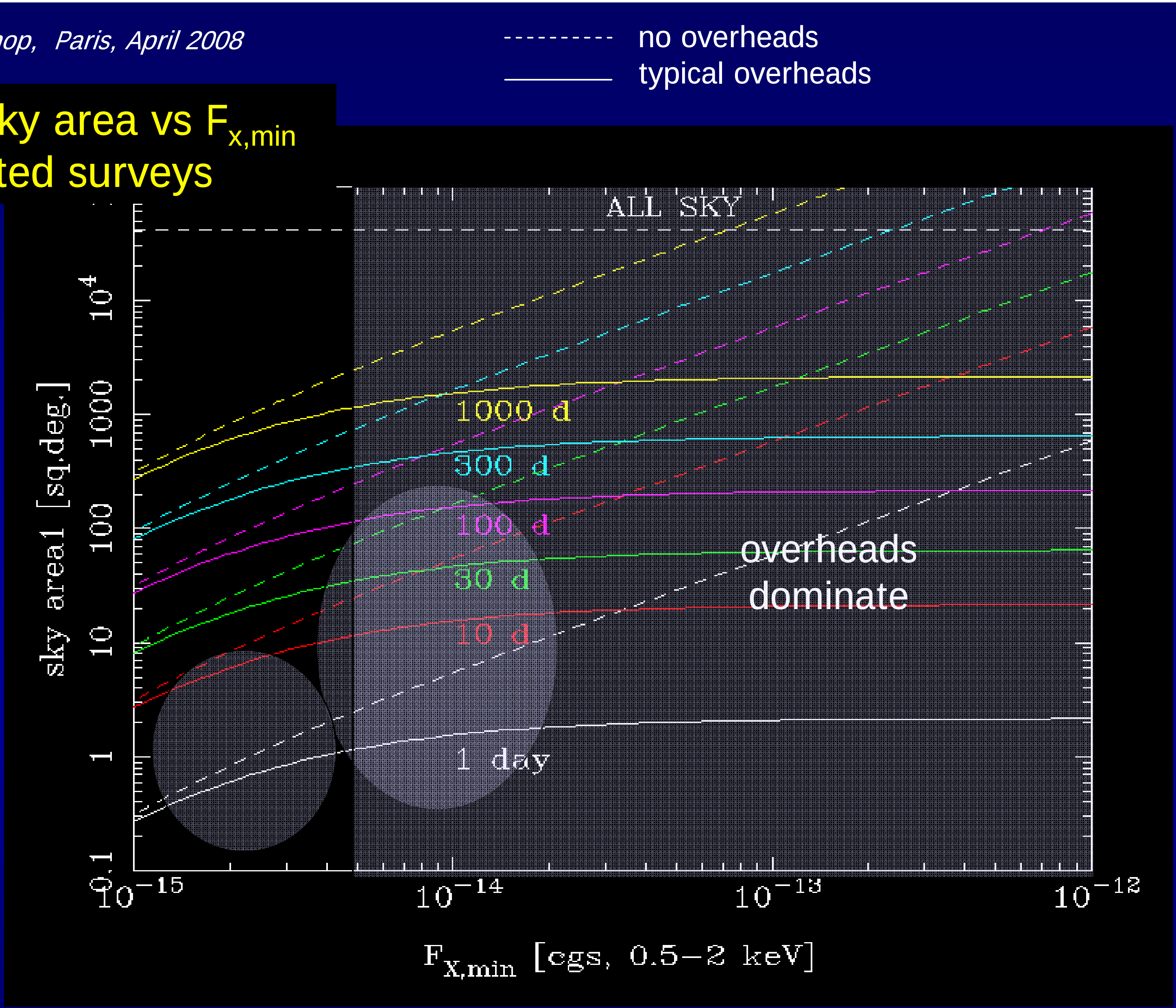
Estimated sky area vs $F_{x,min}$ for pointed surveys



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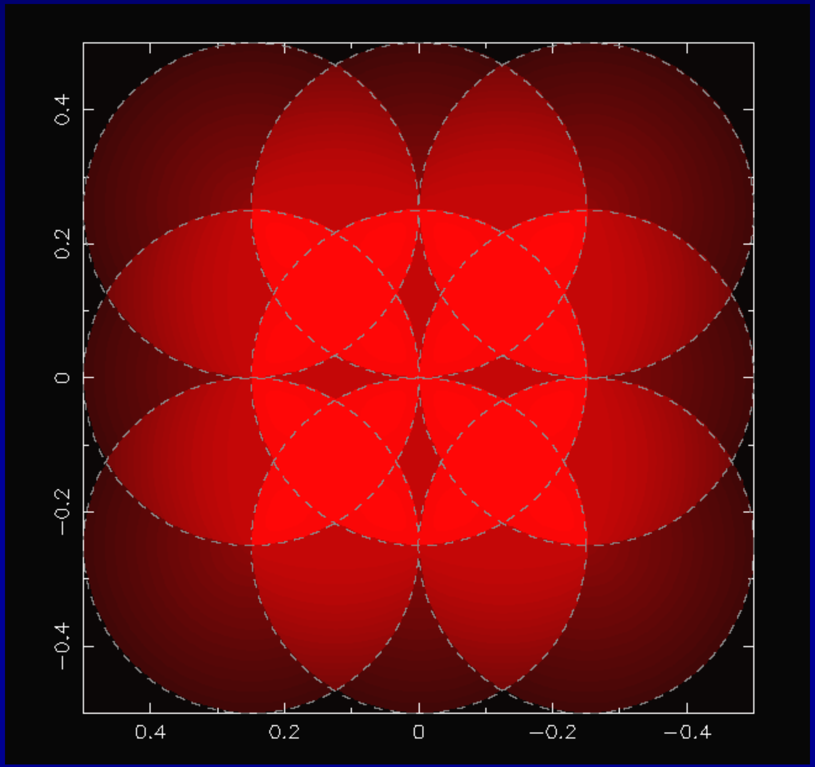
Survey strategies: 1-100 sq.deg regions

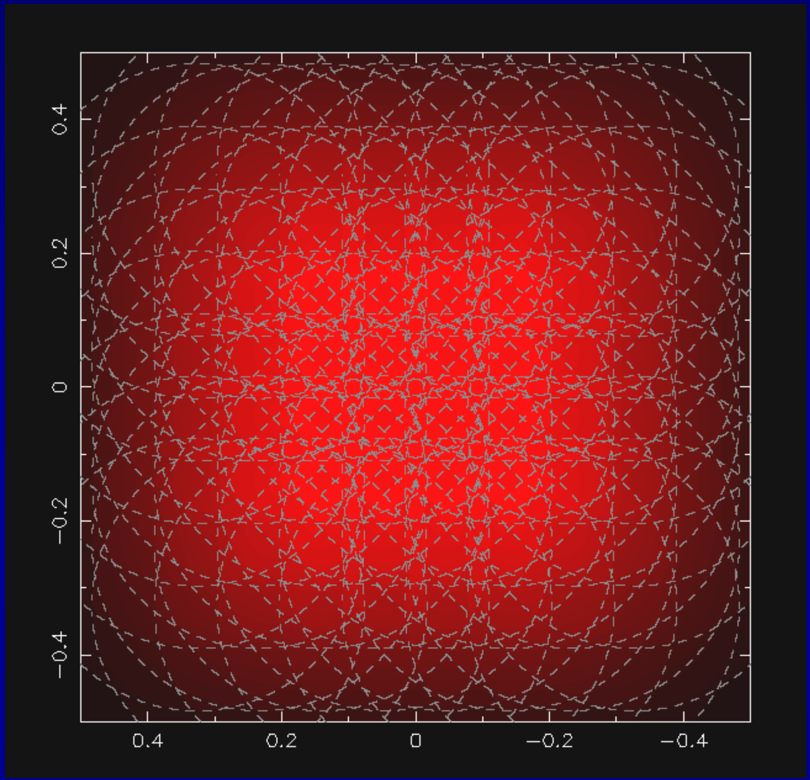
- Such surveys could be considerably improved if XMM had a "raster mode"
  - conceptually a set of (overlapping) **slews** over desired region
  - crucially would avoid multiple pointing overheads
    AND provide significantly better exposure uniformity

- BUT: "XMM-Newton does not have any capability to create a raster of nearby pointings via small aspect motions in an automatic fashion." [XMM UHB] …

- So what about the slow slew survey mode?



3 x 3 pointings covering 1 sq.deg.
15 arcmin separation
highly non-uniform exposure



8 x 8 pointings covering 1 sq.deg.
6 arcmin separation
central exposure very uniform

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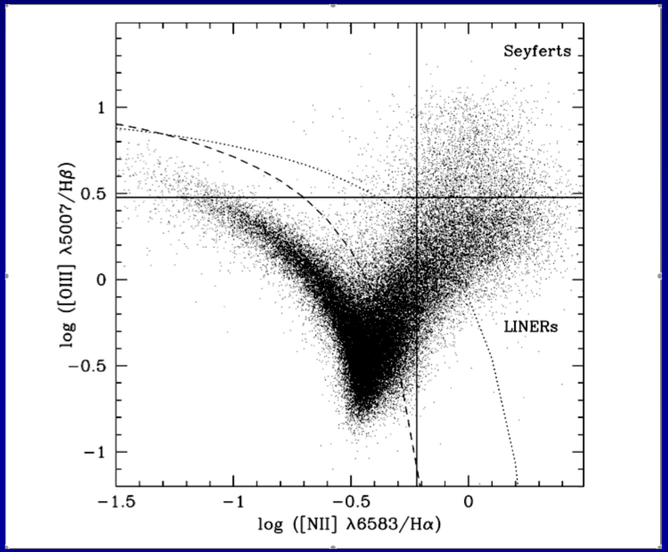
Case study: Search for Compton Thick AGN

- Population of heavily absorbed AGN (Compton Thick ~ $N_H \geq 10^{24}$ cm^{-2}) known to be large locally
- Important for understanding obscured accretion, but poorly constrained
- Rare objects - need large survey, ie 2XMM
- Approach
  - Kauffmann sample**: SDSS AGN selected using line ratios (z<0.3)
    - narrow line objects
  - use $L_{[OIII]}$ as proxy for L_{AGN}
    - not affected by nuclear obscuration
  - select objects with depressed $L_{HX}/L_{[OIII]}$ - signature of CT X-ray absorption



Kauffmann et al., 2003, MNRAS, 346, 1055

Acknowledgements: Dave Alexander, Jonathan Gelbord, Martin Ward ... & Antonis Georgakakis

** DR4 version: http://www.mpa-garching.mpg.de/SDSS/DR4/Data/agncatalogue.html

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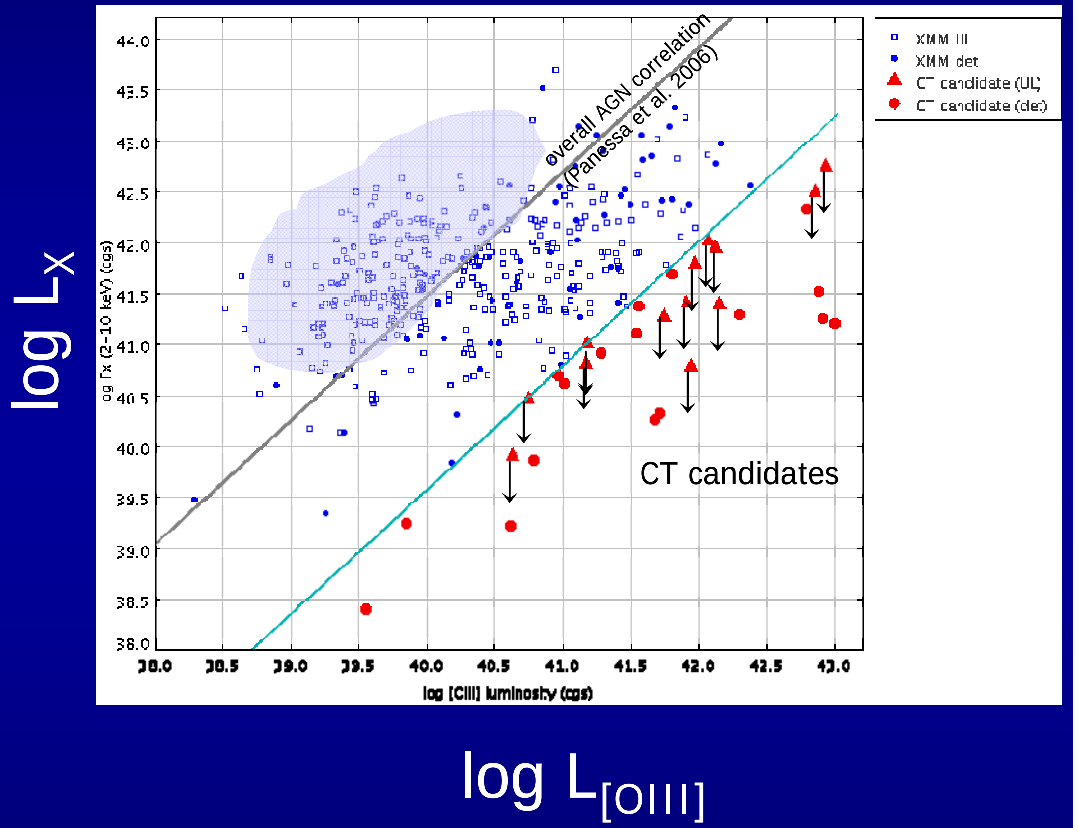
Search for Compton Thick AGN

PRELIMINARY RESULTS

- 403 SDSS AGN covered by 2XMM fields

- 77 detected in 2XMM
- 326 upper limits from 2XMM fields
  - ~50% "useful" UL

- 30 CT candidates (17 det/13 UL)
  - ~ 13% of sample
  - final sample ~20 objects?



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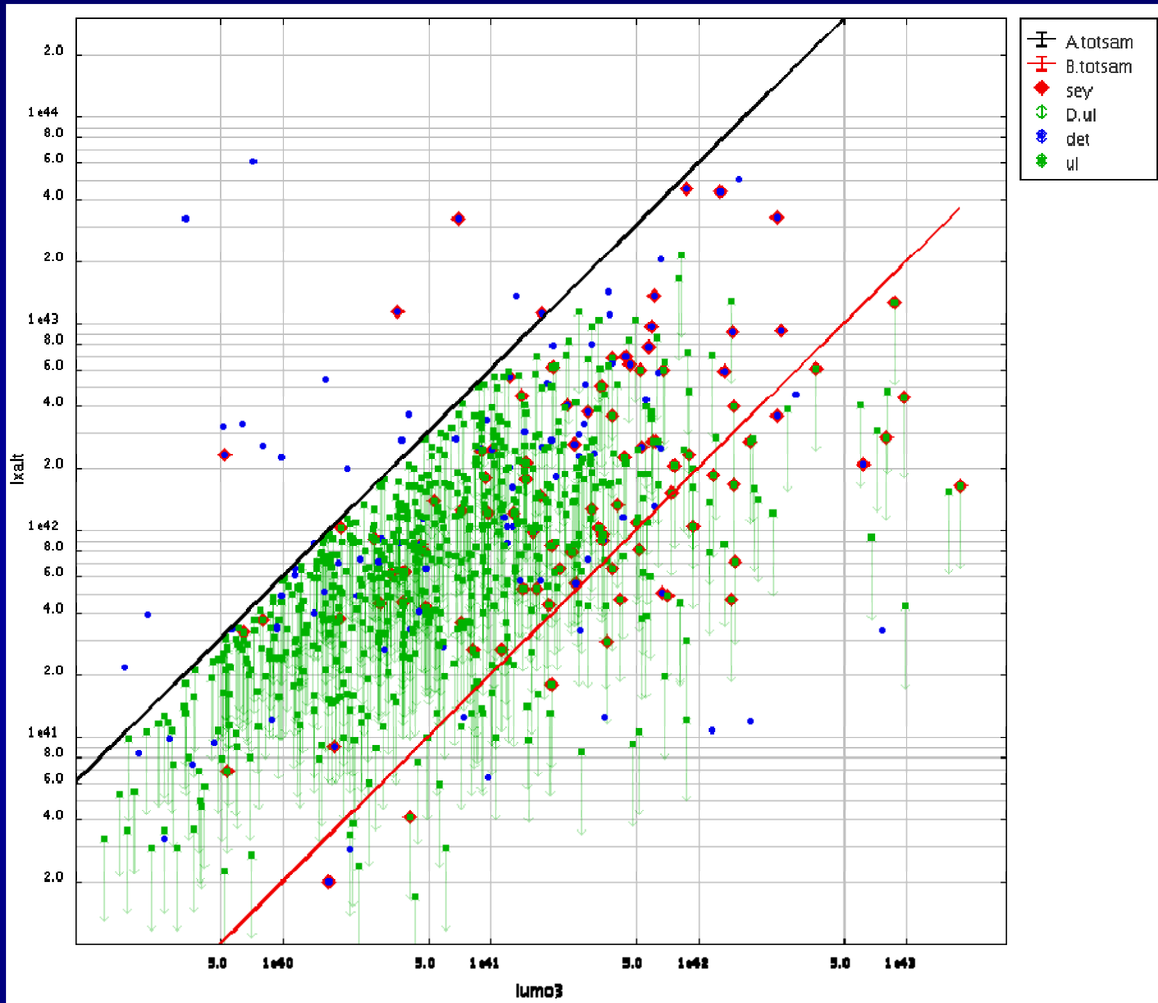

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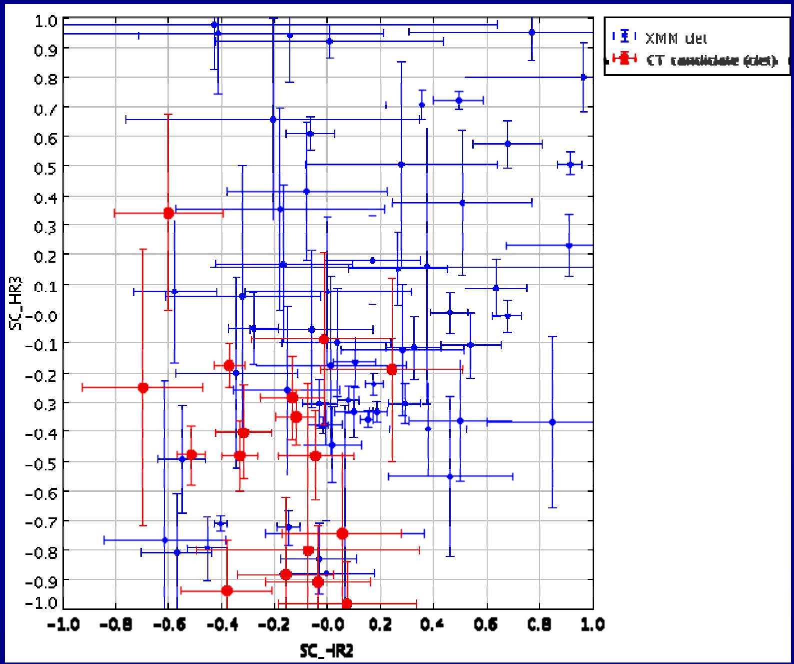
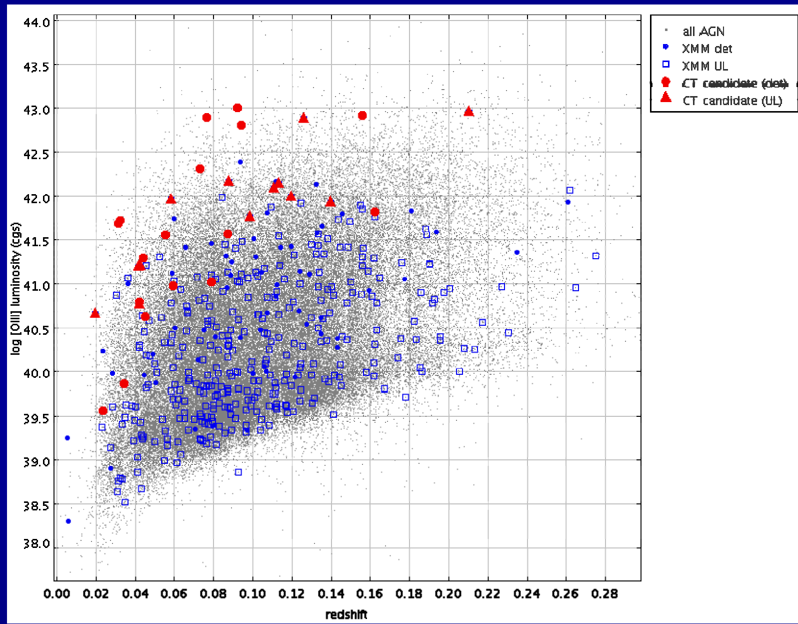
Search for Compton Thick AGN

X-ray colours



$L_{[OIII]}$ vs z



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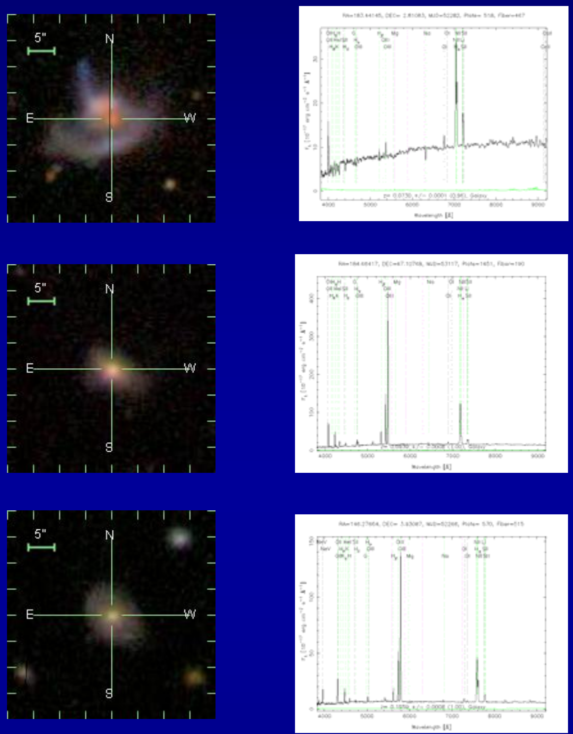
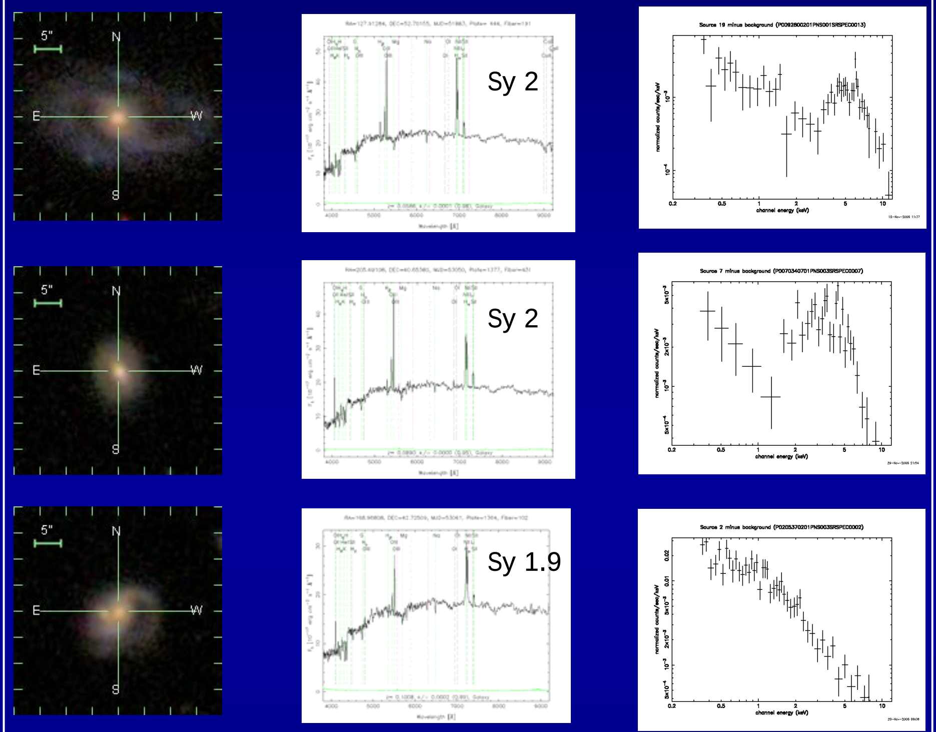
Search for Compton Thick AGN



IRAS 12112+0305
ULIRG

too faint
for X-ray spectra



$L_X/L_{[OIII]} < 0.01\ L_X/L_{[OIII]}$(normal)

CT candidates

$L_X/L_{[OIII]} \sim 0.1\ L_X/L_{[OIII]}$(normal)

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