Contiguous and serendipitous surveys with XMM-Newton

Mike Watson
XMM-Newton Survey Scientist

XMM-Newton SURVEY SCIENCE CENTRE

Topics

- Comparison between planned (contiguous) and serendipitous sky surveys with XMM
  - *blatant advert for 2XMM catalogue*
  - do we need planned surveys?
- What could be achieved with new planned surveys?
- Comments on survey strategies

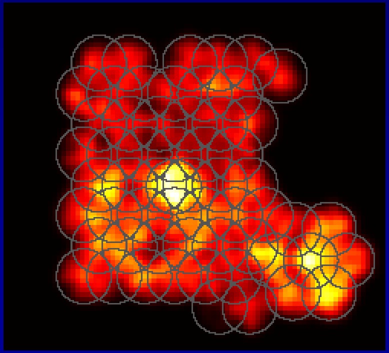
Mike Watson
Leicester University

Existing surveys with XMM-Newton

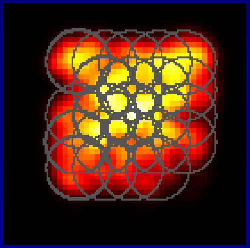
Contiguous (planned) surveys

(relatively wide angle)

- AO programs (pointed obs. mosaics)
  - eg LSS, SXDS, COSMOS …
  - 1-10+ sq.deg.
  - $f_{x,min} \sim 10^{-15} - 10^{-14}$
  - + shallower surveys in Galactic plane



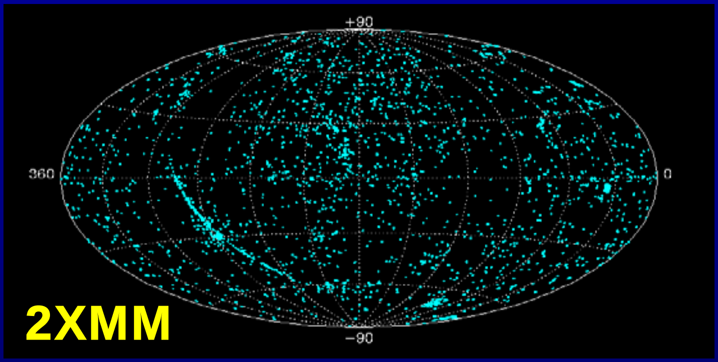
LSS & SXDF (public data)



COSMOS (public data)

Serendipitous Sky Survey

- ~90 sq.deg/year, >600 sq.deg. to date $f_{x,min} < 10^{-14}$
- constructed from whole pointed program



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XMM serendipitous sky survey & XMM Catalogues

- XMM serendipitous sky survey: serendipitous source content from each pointed observation (EPIC data)

⇒ **XMM serendipitous X-ray source catalogues produced by XMM SSC**

- 1XMM catalogue (2003): based on 585 XMM observations
- 2XMMp catalogue (2006): pre-release version of full 2MM catalogue, based on 2400 XMM observations with highest quality

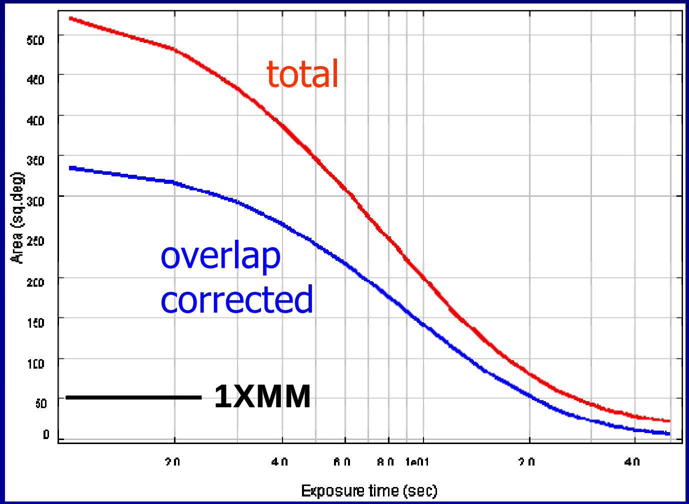
- 2XMM catalogue: full catalogue, currently being finalised
  - 3491 observations
  - public release July 2007

2XMM Catalogue

- **2XMM: largest X-ray catalogue ever**
  - 247K detections → 192K unique sources
  - 520 sq.deg. / 330 sq.deg. overlap excluded
  - "science grade" catalogue
- **Available by mid July 2007**

- 2XMM is ~50% larger than 2XMMp
- 3491 observations vs 2400 in 2XMMp

2XMM Sky Area



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

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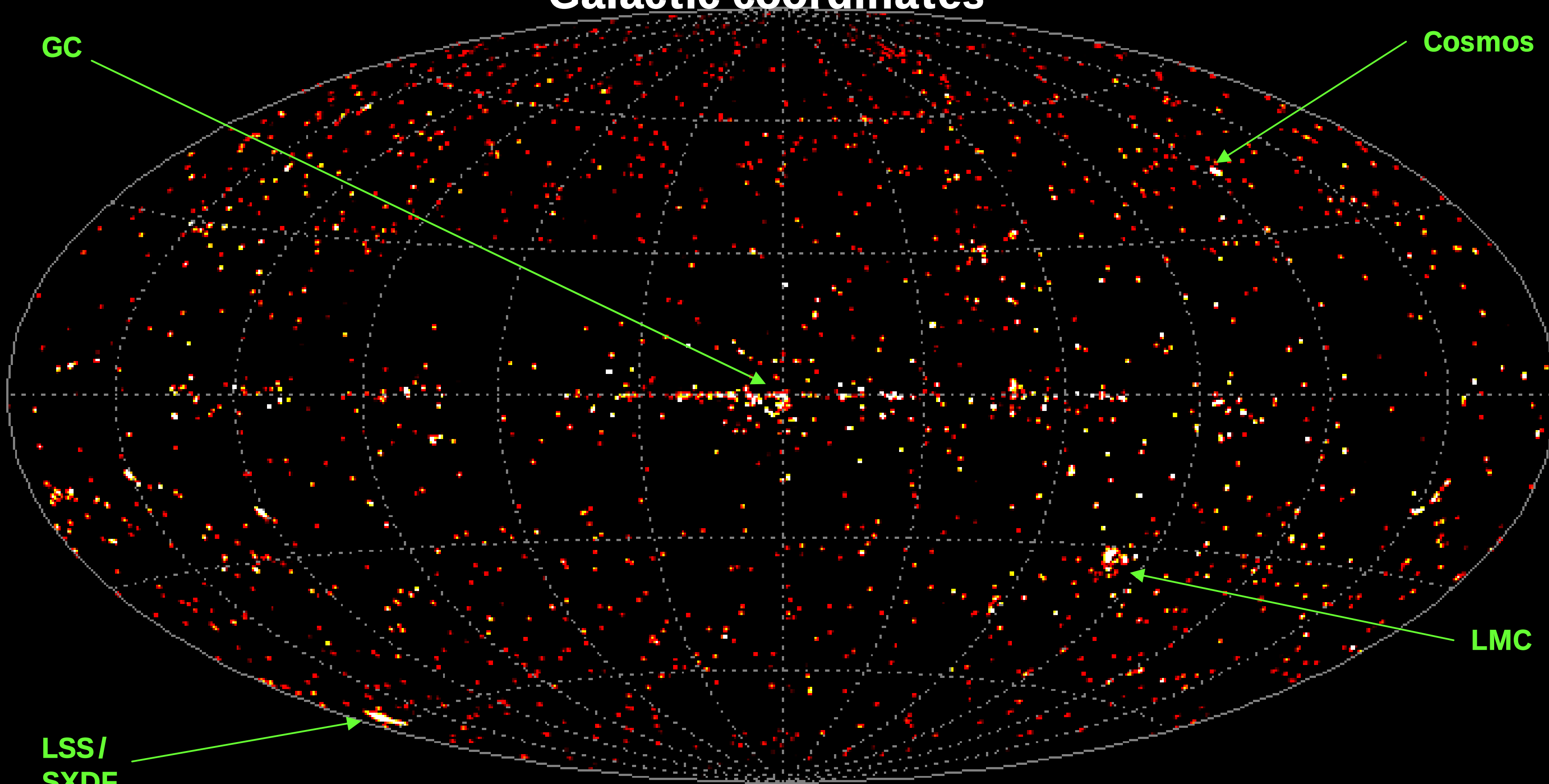
2XMM source density map

Galactic coordinates



2XMM is largest X-ray source catalogue ever produced

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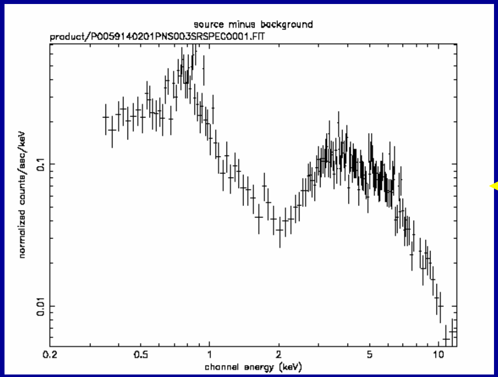
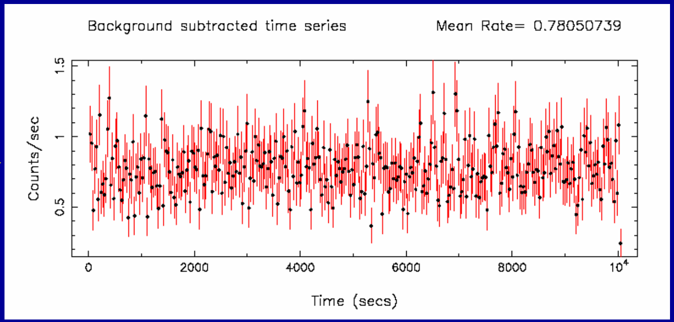
2XMM products



X-ray spectrum

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



time series

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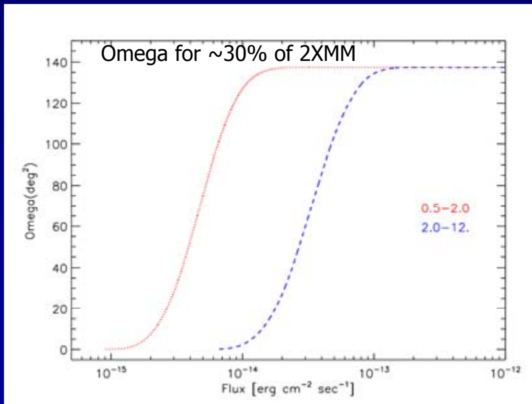
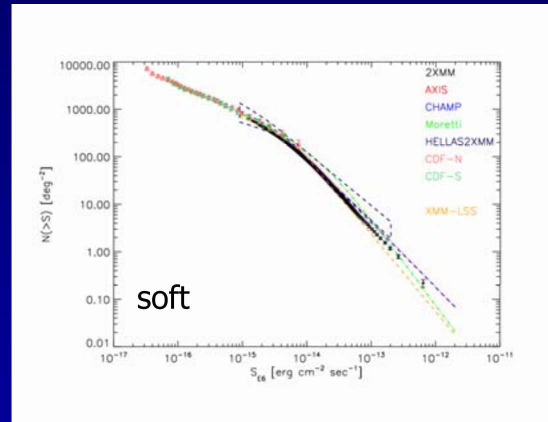
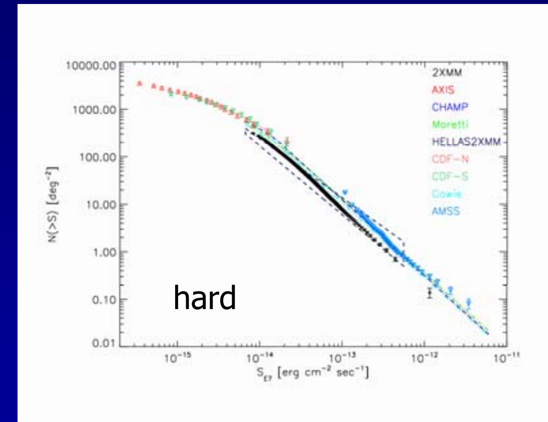
area vs sensitivity



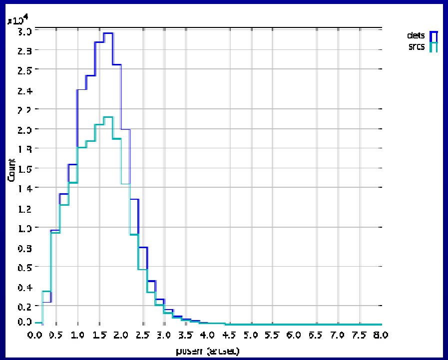
preliminary log N – log S





Courtesy Silvia Mateos, 2XMM log N – log S in preparation

position errors
$\langle\sigma\rangle$ = 1.5 arcsec



typical (deepest) sensitivity limits

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

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

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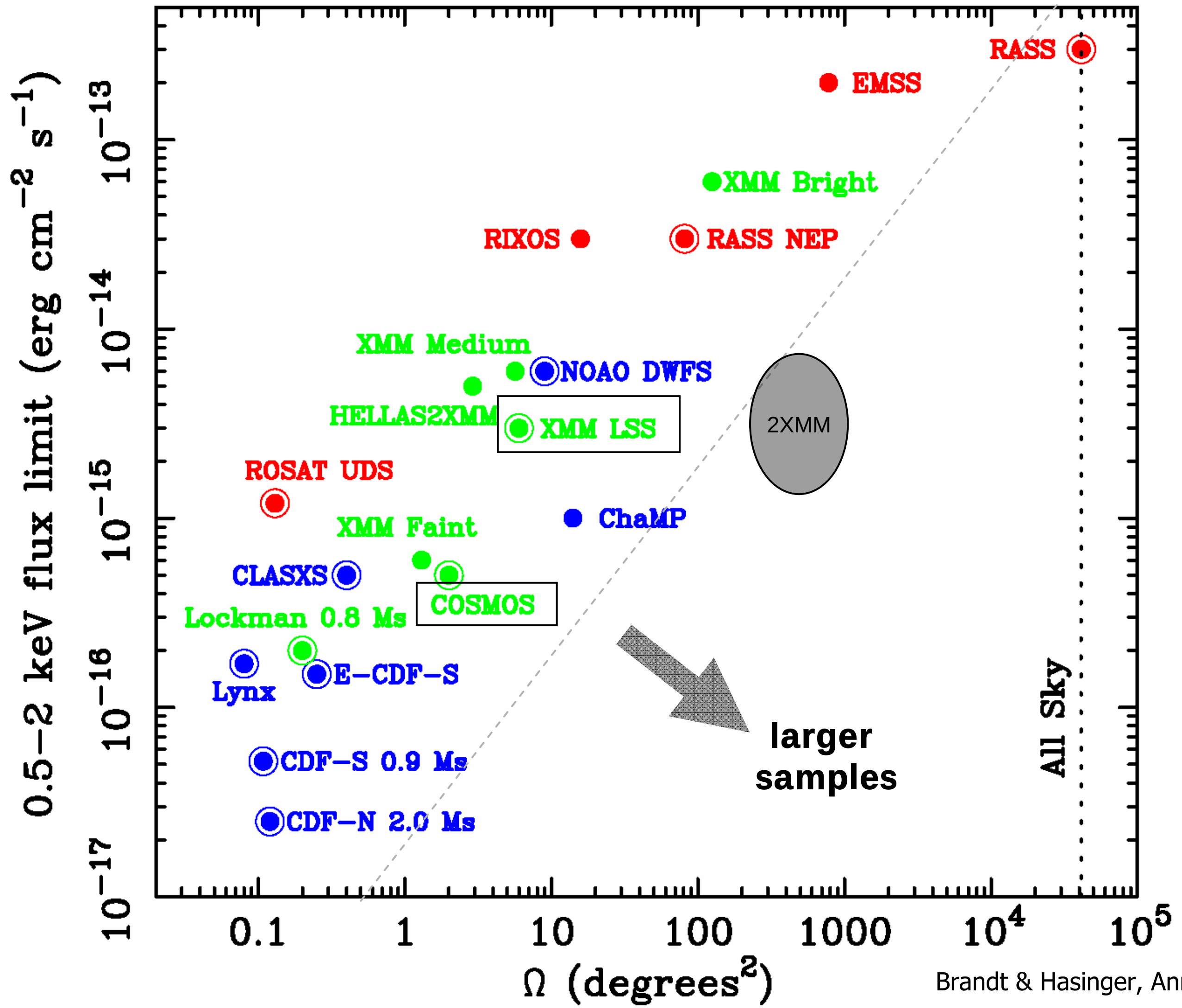
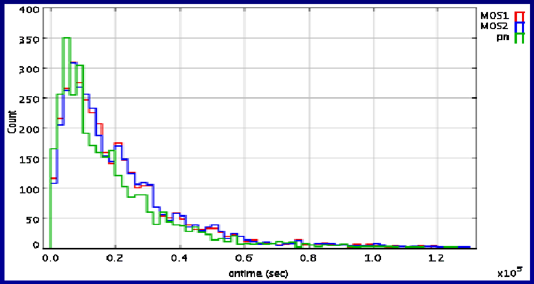


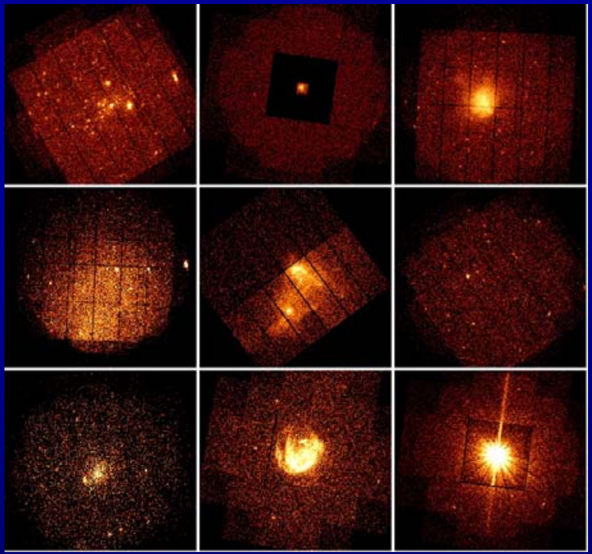
Brandt & Hasinger, Ann Rev

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
    - (eg >20% have only pn small window mode)
- Image content/quality issues for survey science
  - bright point sources (PSF wings & OOT events)
  - bright extended sources
  - image defects
- Net effect for surveys
  - ~30% OK
  - 20-50% some image area not useful
  - 10% marginallly useful / 10% useless

observation time per field





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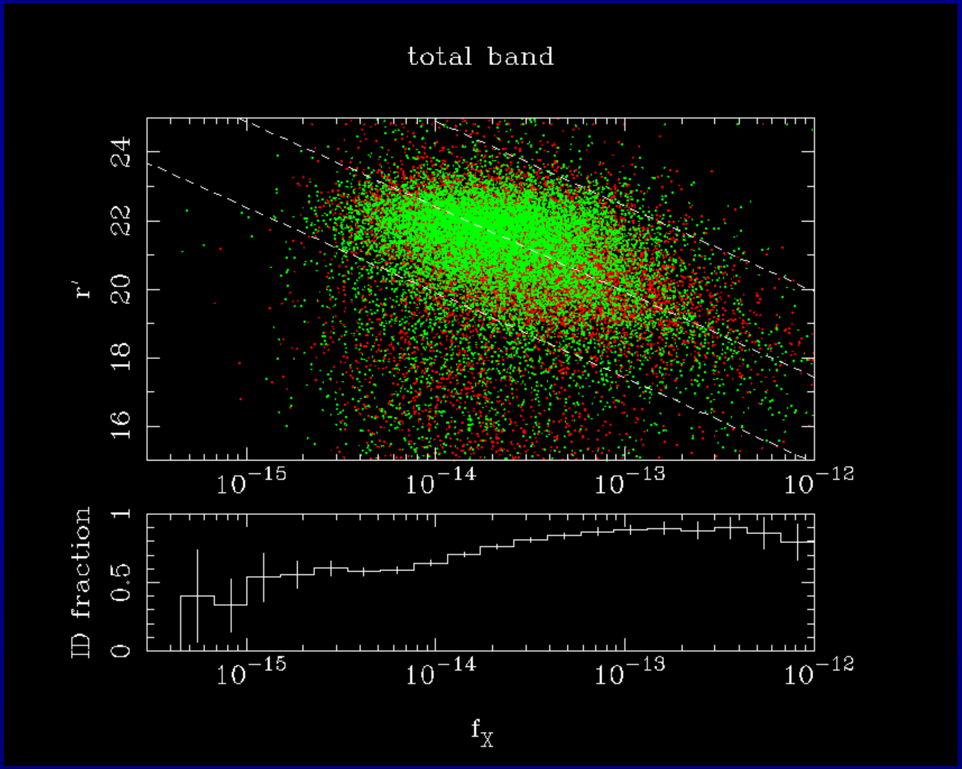
Importance of identifications: other $\lambda\lambda$ data

- 2XMM alone: X-ray colours, X-ray spectra/time series (15% of total), X-ray morphology
- Most science projects require "identifications", ie match with objects at other λ
- Current identifications for 2XMM catalogue sources
    - Optical / IR
        - SDSS DR5: 27000 sources in joint sky area (~26% at present) but not deep enough (22^m vs $>24^m$)
        - [UKIDSS/VISTA will eventually cover 30-50% of XMM sky]
    - prospects for mid-IR/submm/radio ?
    - Optical /IR spectroscopic IDs
        - few percent of total
- **Obtaining IDs is very tough for serendipitous surveys**
    - until all-sky resources reach required depths…

2XMM cross-match with SDSS DR5

- 26% of 2XMM sources lie in SDSS DR5 region
- Positional cross-match ⇒ ~27000 secure "photometric" SDSS
  - chance match rate ~few percent
- Overall ID fraction >50%, but strongly dependent on f_X
- 1600 matches have SDSS spectra (5.6%)
  - ~40% galaxies (ALG/NELG)
  - ~60% BL AGN
  - few percent stars



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Leicester University

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 $\lambda\lambda$**
  - time variability: potentially available from repeated scans

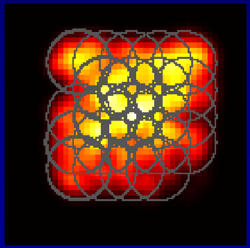
→ factor 3-10 more efficient than serendipitous data (for same area)

Mike Watson
Leicester University

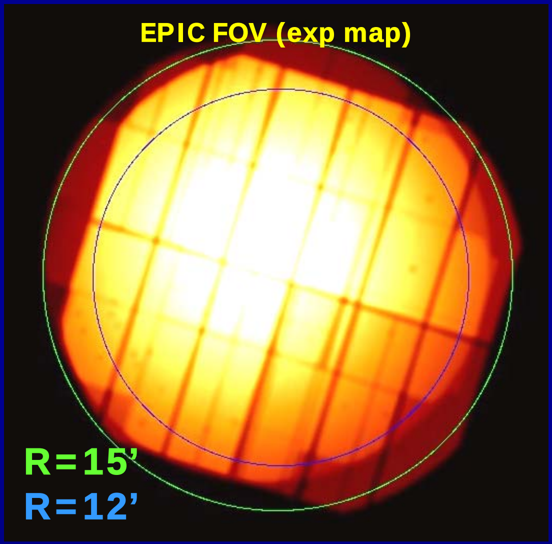
Survey strategies

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?

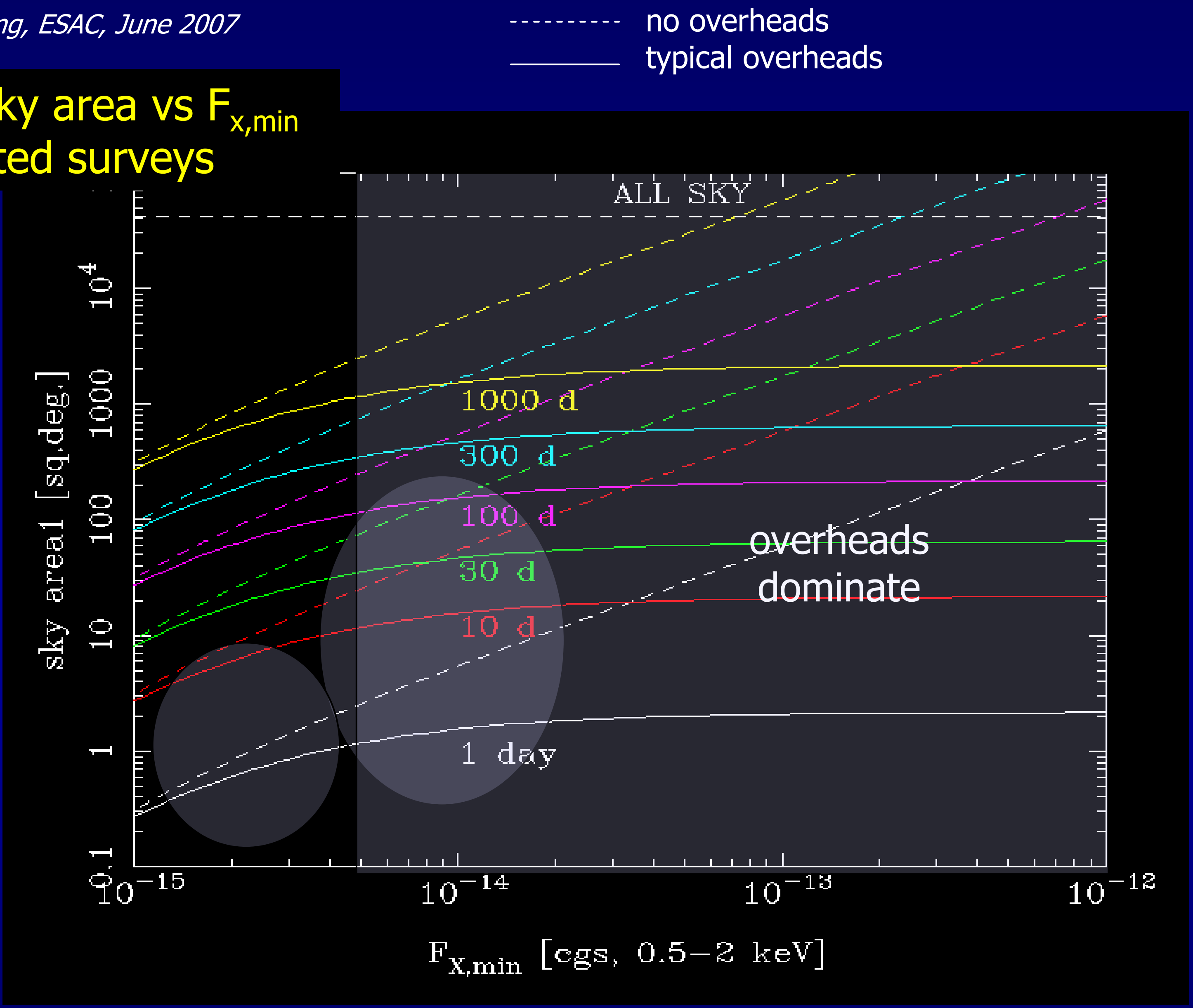


COSMOS (public data)



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

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



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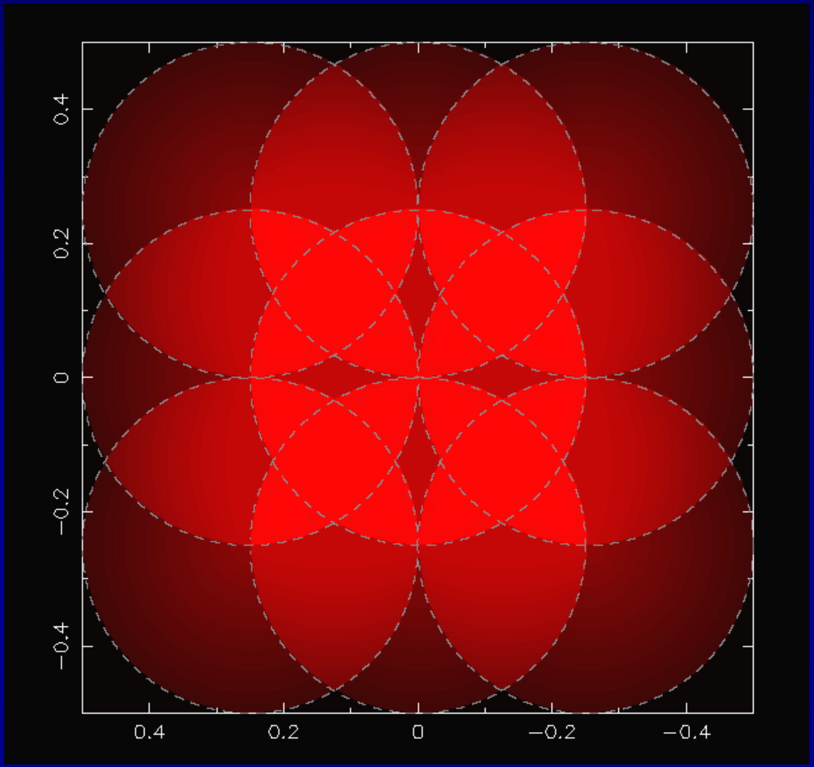
Leicester University

Survey strategies: 1-100 sq.deg regions

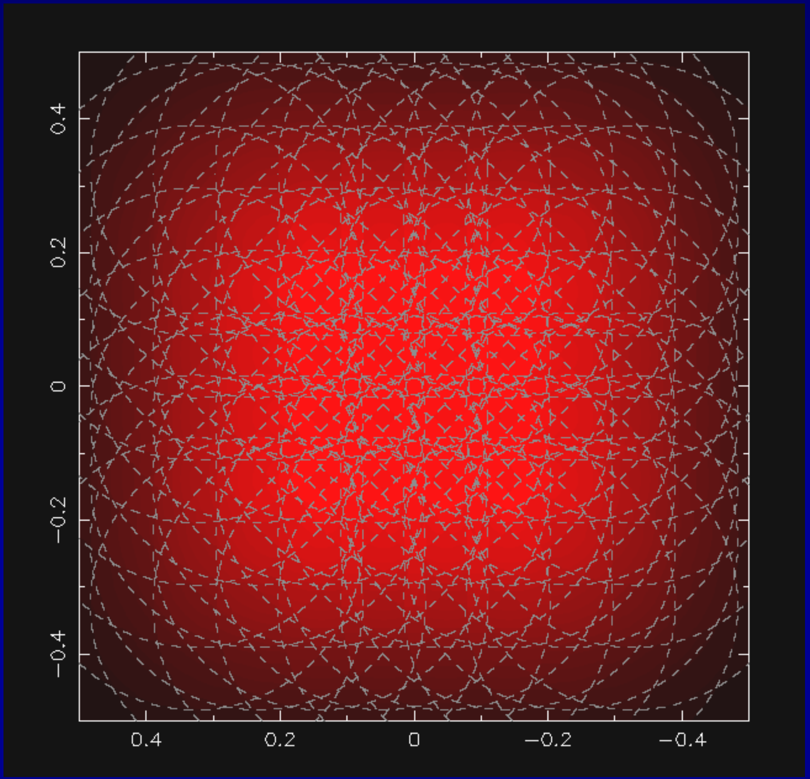
- Such surveys could be considerably improved if XMM had a "raster mode"
  - conceptually a set of (overlapping) **slews** over desired region
  - crucially would avoid multiple pointing overheads
    AND provide significantly better exposure uniformity

- 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

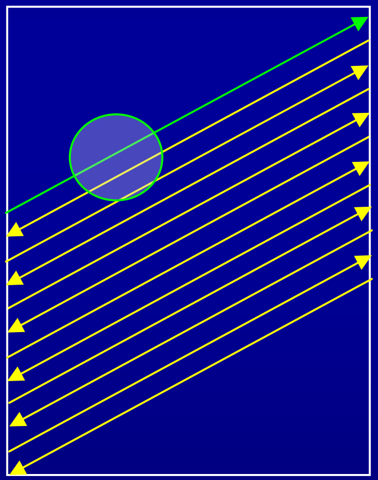


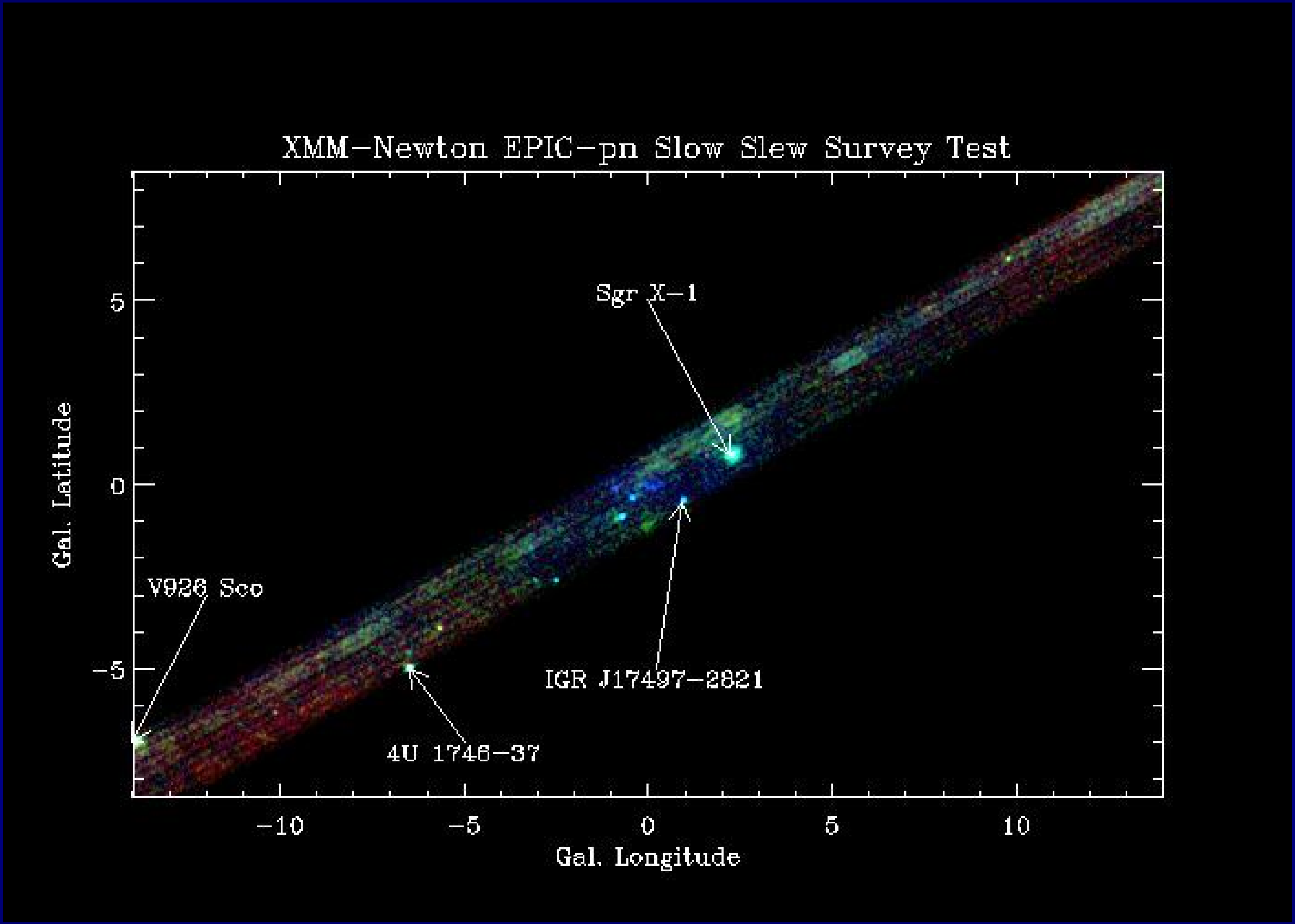
8 x 8 pointings covering 1 sq.deg.
6 arcmin separation
central exposure very uniform

Mike Watson
Leicester University

Slow slew survey mode

- Existing slews between pointings have been used to construct the **XMM Slew Survey**
  - already covered >8000 sq.deg. with typical exposure T~6 sec.
  - XMMSL1 slew survey catalogue: clean version has ~3000 sources with median flux ~10^{-12} (soft) ~10^{-13} (hard)
- New slow slew survey mode tested Sept.2006
  - aims to support PLANNED slews to cover significant sky area





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Leicester University

Issues with slow slew survey

- Slowest slew rate is currently 30 deg/hr
  - effective exposure per slew ~40 sec (EPIC pn)
  - deeper surveys require 100s of overlapping slews
- Slew path accuracy depends on slew direction
  - issue for achieving desired sky coverage
- Slews must comply with observing constraints
  - 70-110 deg to sun
  - "natural" slew path along ecliptic longitude
    - poor match to some survey regions (eg Galactic plane)
- Short slews inefficient due to significant turn-around overheads
  - slew lengths ~10s of degrees
- Effects of space weather – loss of coverage in high background

$\Rightarrow$ slow slew survey mode currently seems optimised only for very shallow exposures of large sky areas

Mike Watson
Leicester University

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 science (LSS) or follow-up/ID
  - depth >20 ksec
- New wide angle surveys with XMM would benefit significantly from a raster scan mode: enhancements/improvements to slow slew survey mode?

Mike Watson
Leicester University