A MODIFIED SOURCE-DETECTION METHOD FOR THE NEXT XMM-NEWTON CATALOGUES AND BEYOND

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XMM2ATHENA WP4: **Adriana Mancini Pires, Sudip Chakraborty, Axel Schwope, Jean Ballet, Georg Lamer, and consortium partners**

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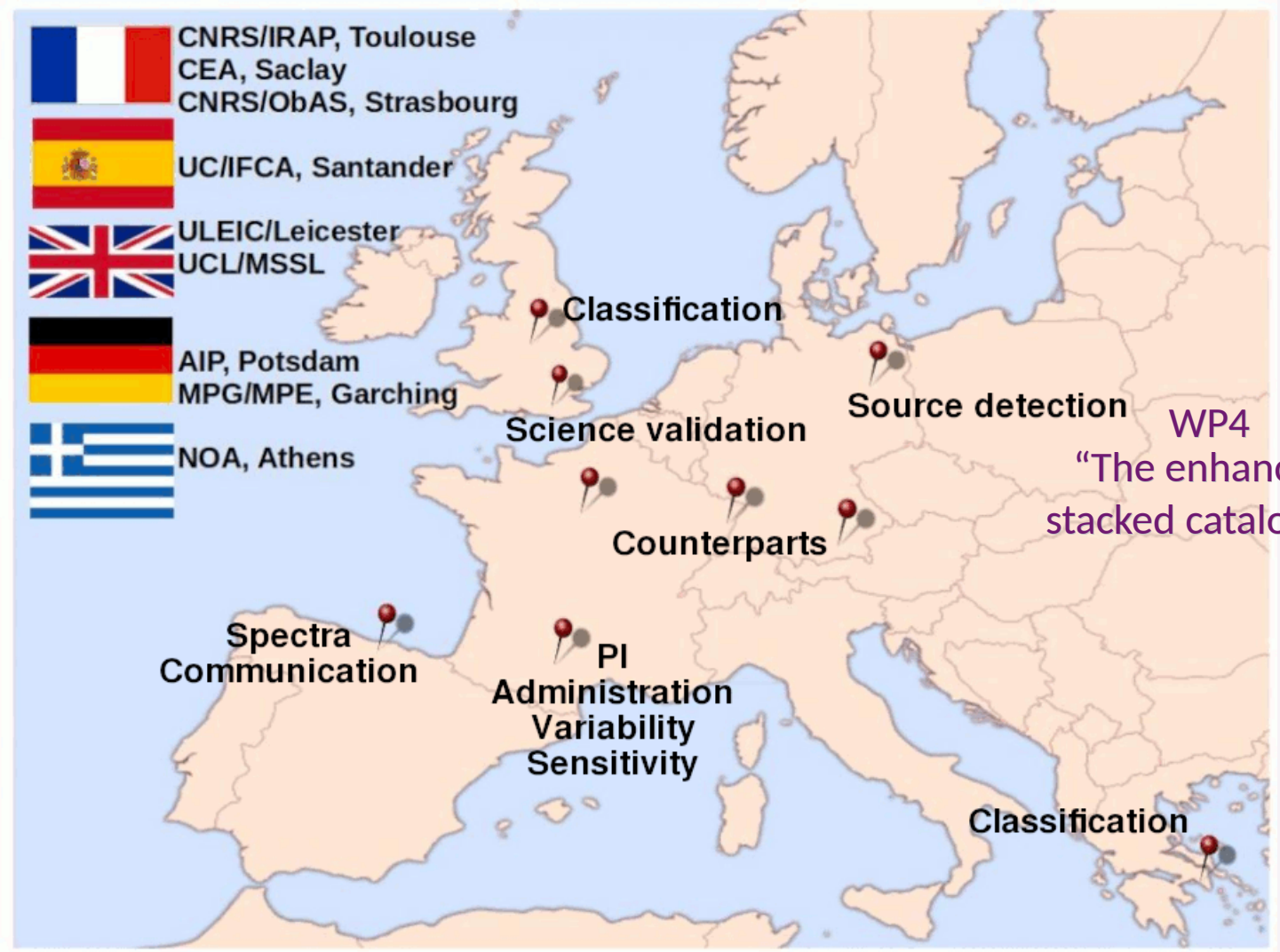
H2020 XMM2ATHENA & WP4



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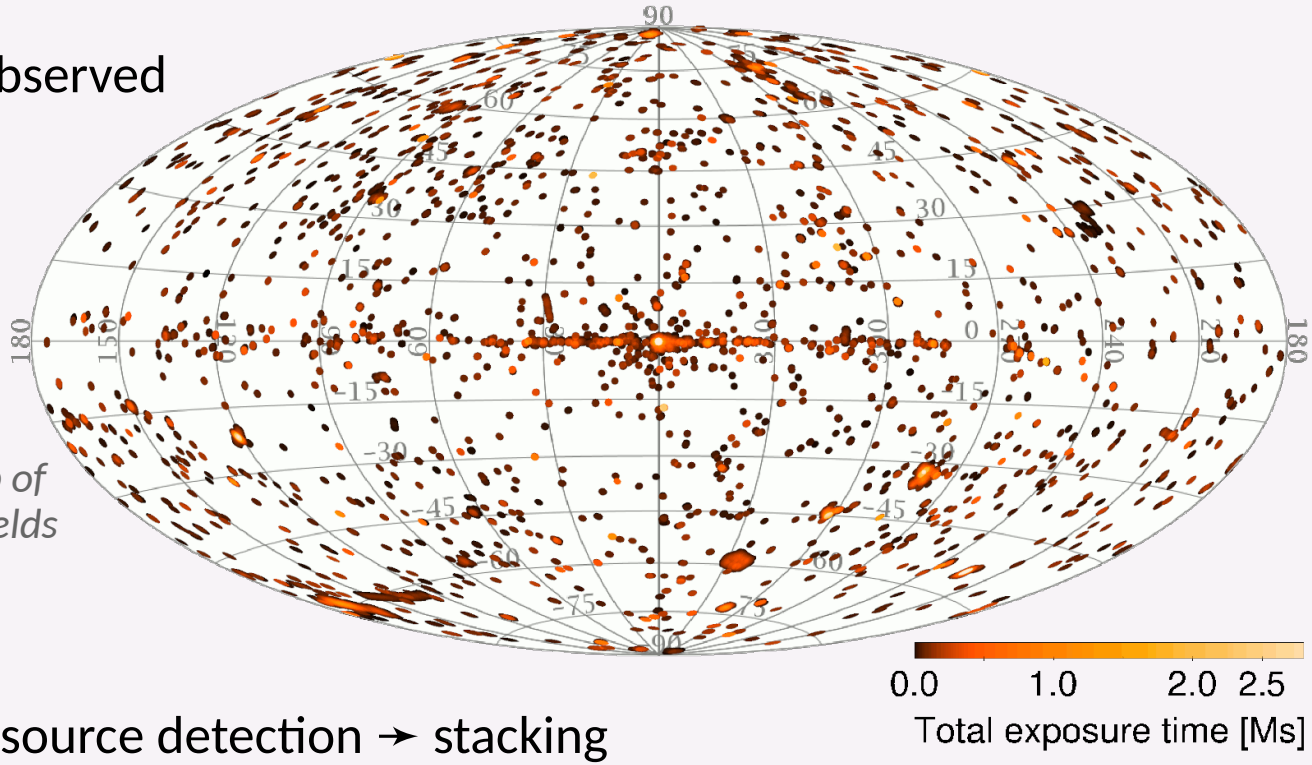
OBJECTIVES: "STACKED"

➤ Six catalogues from overlapping XMM-Newton observations since 2018

Explore the multiply observed

XMM-Newton sky:



XMM-Newton sky map of repeatedly observed fields

* individual standard source detection ➛ stacking
* longer accumulated exposure time per source
* higher sensitivity and accuracy + long-term variability

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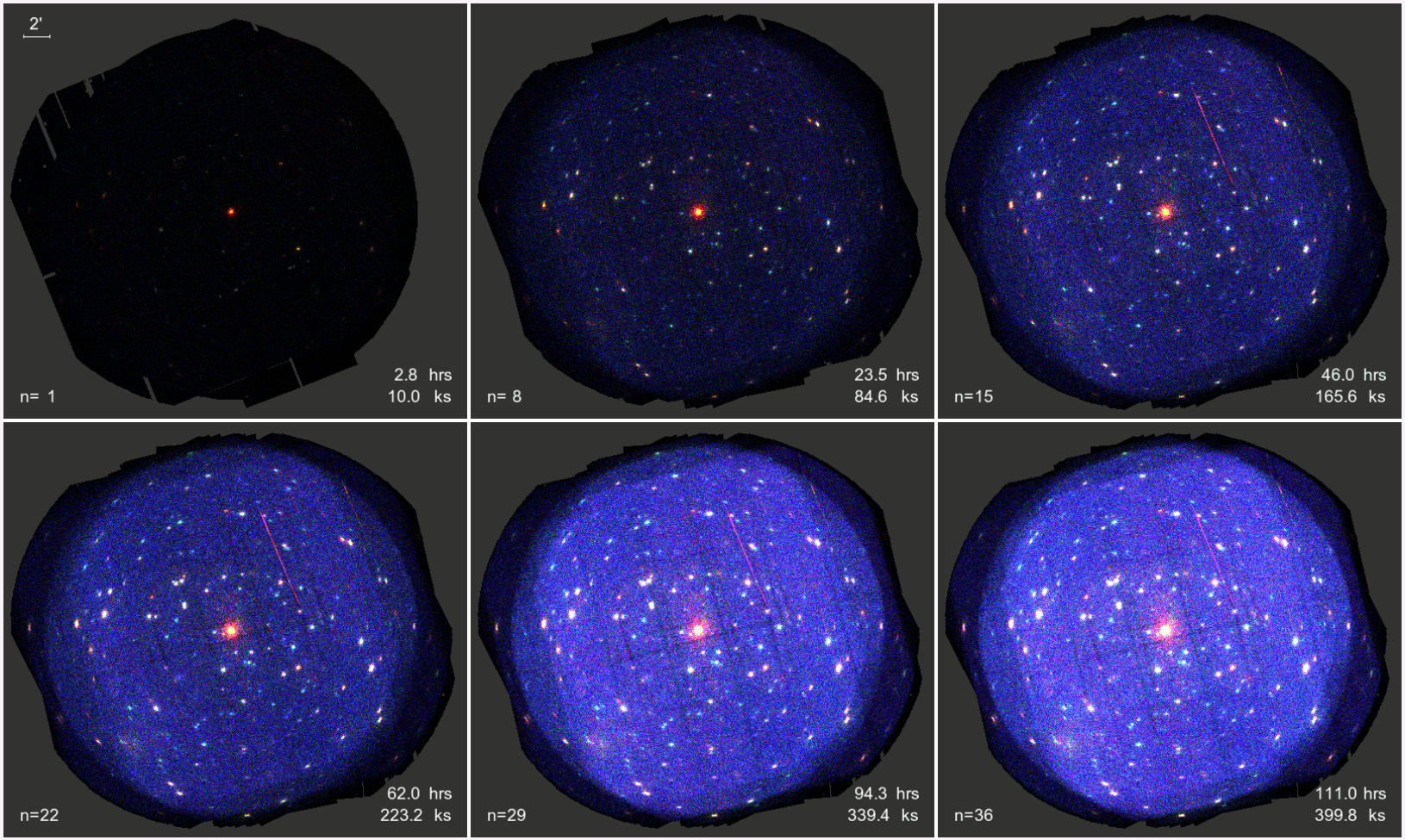
OBJECTIVES: "STACKED"

- Digging deeper: more (fainter) sources through long combined exposure time



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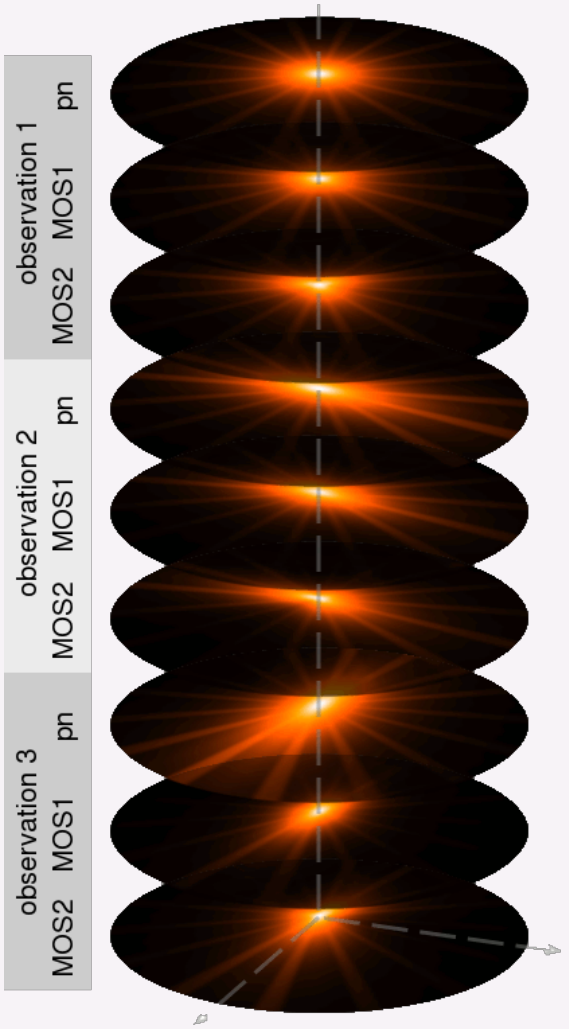
OBJECTIVES: "ENHANCED"

- Current approach:
  - simultaneous maximum-likelihood PSF fitting
  - free count rate (flux): → "rates mode"
    energy bands, instruments, observations
- Gain:
  - higher sensitivity
  - improved source parameters
  - fewer spurious detections
  - source variability without matching
- Downside:
  - sensitivity limited mathematically
    through high number of free fit parameters



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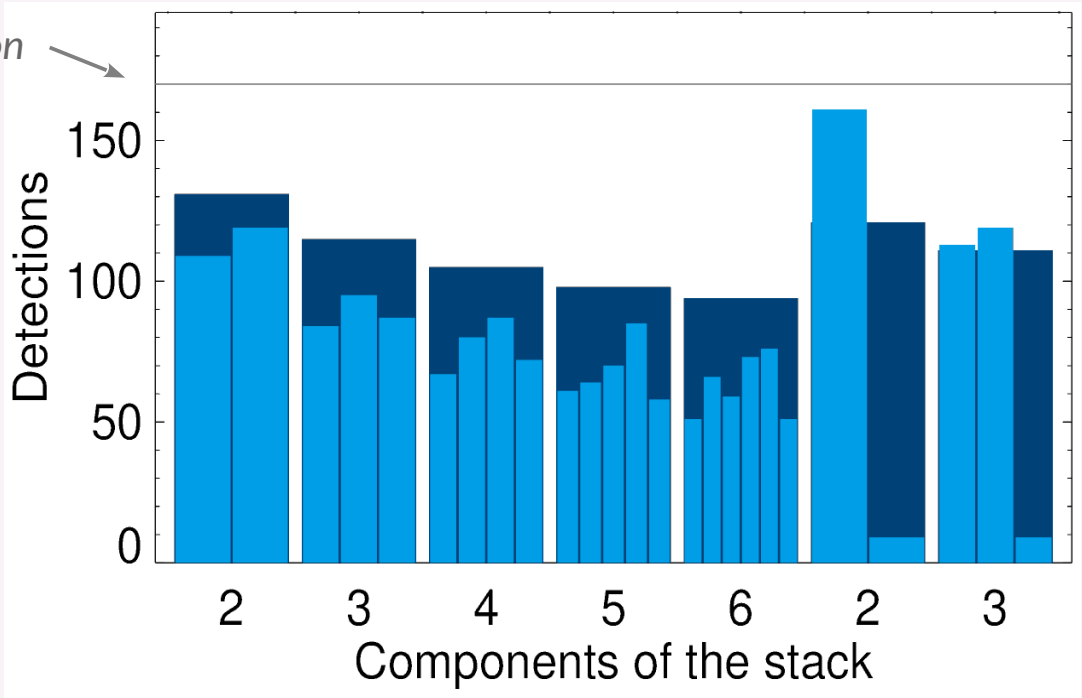
OBJECTIVES: "ENHANCED"

- Test: split >100ks observations and run source detection on snippets:

Stacks better than single, un-interrupted better than stacks,
fewer interruptions better than many.



Sources detected in stacks of an artificially split observation

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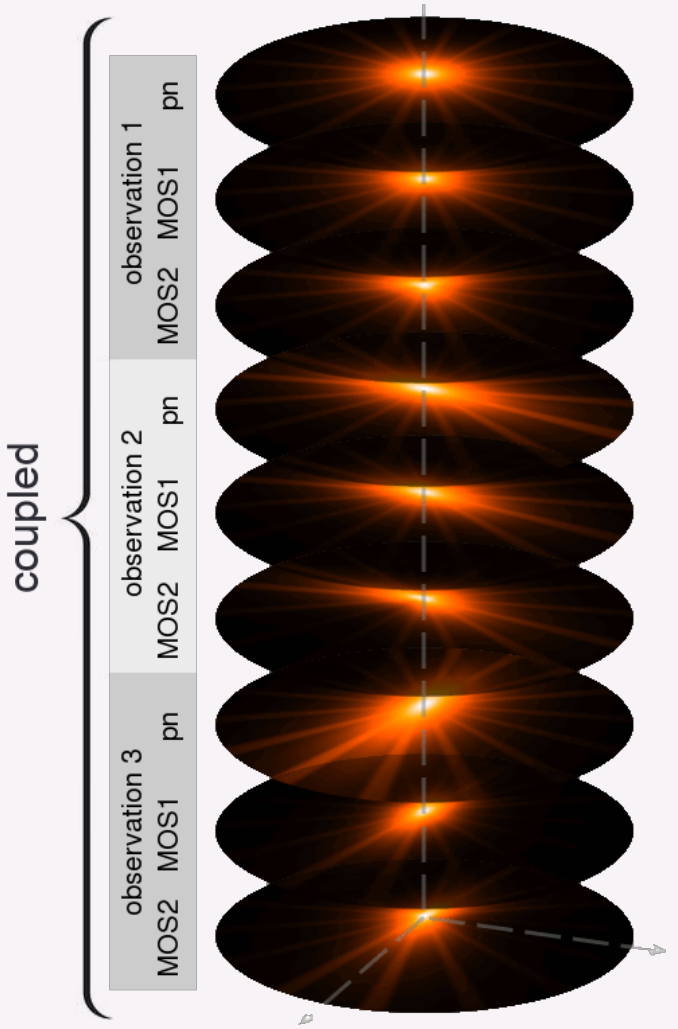
OBJECTIVES: "ENHANCED"

- New approach: constant source flux
  - instruments: known
  - observations: assumed
  - energy bands = spectral shape: assumed & fitted
    → "spectral mode"

- Expected additional gain:
  higher sensitivity
  through significantly fewer degrees of freedom

- Downside:
  - no variability information
    through source detection as before → *handled*



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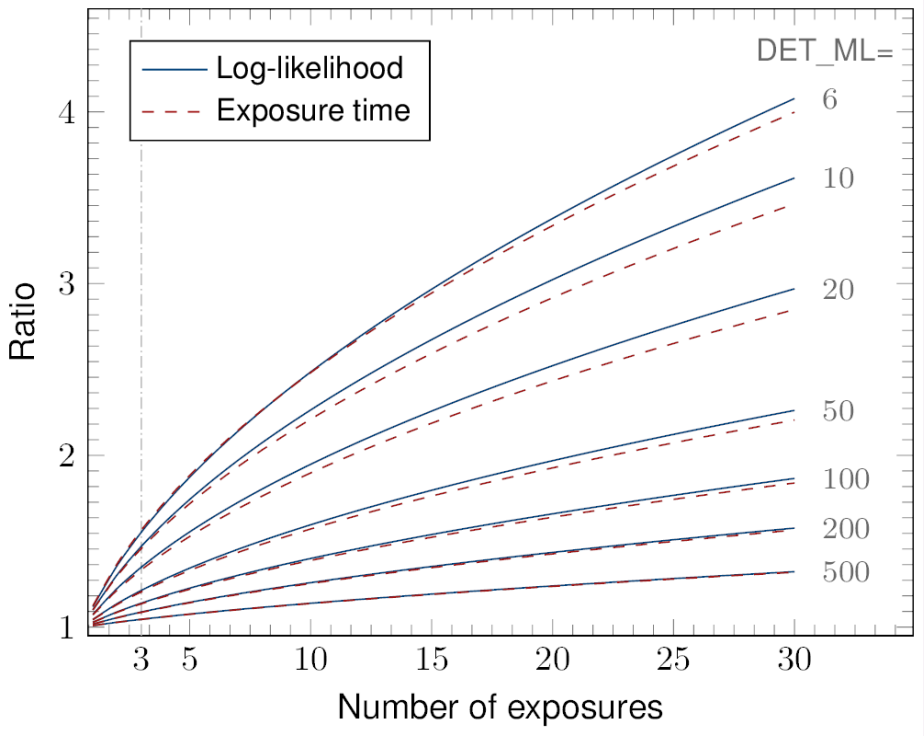
SOURCE DETECTION & SPECTRAL FITTING

- flux coupling as an alternative task mode:
  - fit an absorbed power-law spectrum to five energy bands of each individual source in particular for future catalogues
- How-to?
  - physical quantity: flux
  - measured quantity: count rate (photons/time)
  - relation: energy conversion factors (ECFs)



Ideal increase of detection likelihood (sensitivity)

(Equations provided by Jean Ballet)

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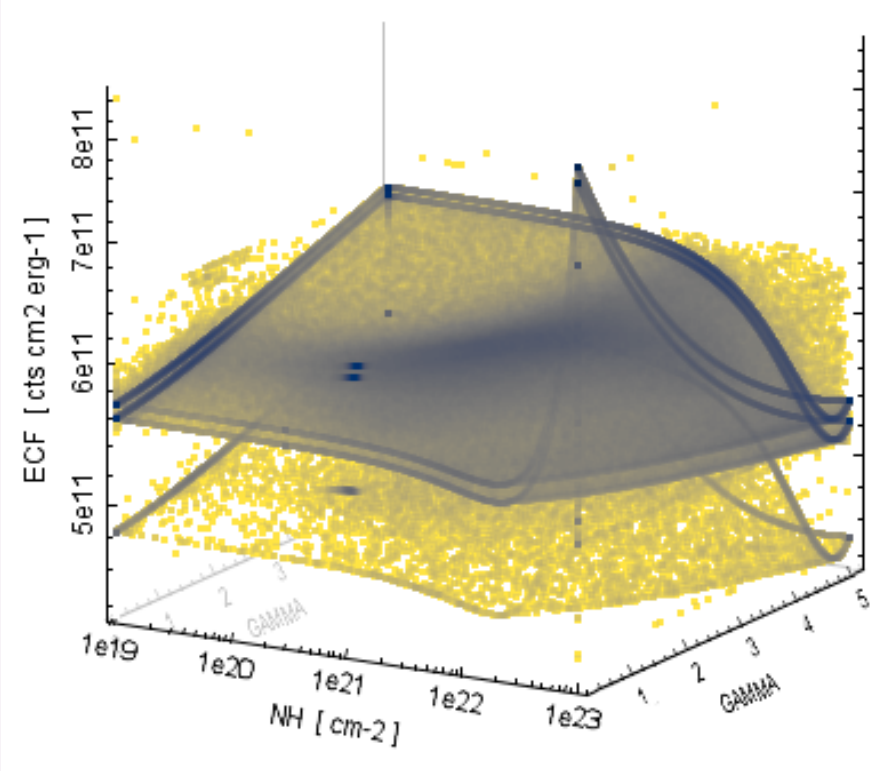
NEW MODE – ENERGY CONVERSION FACTORS

➤ conversion between measured count rates and modelled flux

ECF module by Saclay:

* assuming a power-law spectrum
* ECF and flux ratio for different sets of power-law index & absorption
* ongoing: optimisation additional spectral models



Energy conversion factors in EPIC/pn band 3

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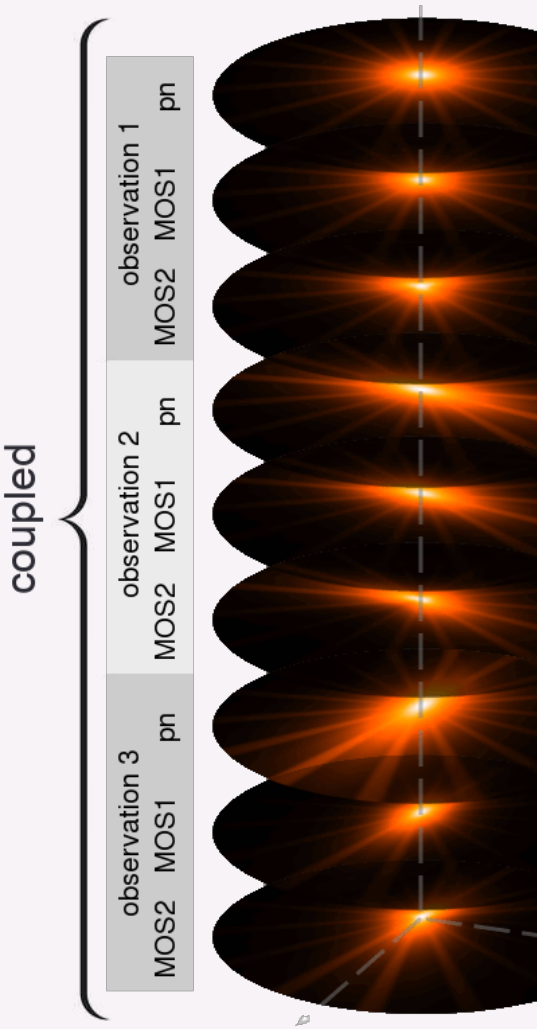
NEW MODE – RE-DESIGNED SOURCE DETECTION

- Flux-coupled source detection
  - fit position, extent, common flux, spectral parameters
  - integrate the ECF interface in spectral fitting
  - *adjust the maximum likelihood routine*
  - *determine detection likelihood and parameter errors*
  - determine final source parameters and variability info from subsequent PSF photometry
  - optionally switch between detection modes
- Tests & proto-catalogues → *talk by Adriana M. Pires*



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ARTIFICIALLY SPLIT OBSERVATIONS: RATES MODE

➤ Test: split >100ks observations and run source detection on snippets:

Stacks better than single, un-interrupted better than stacks,
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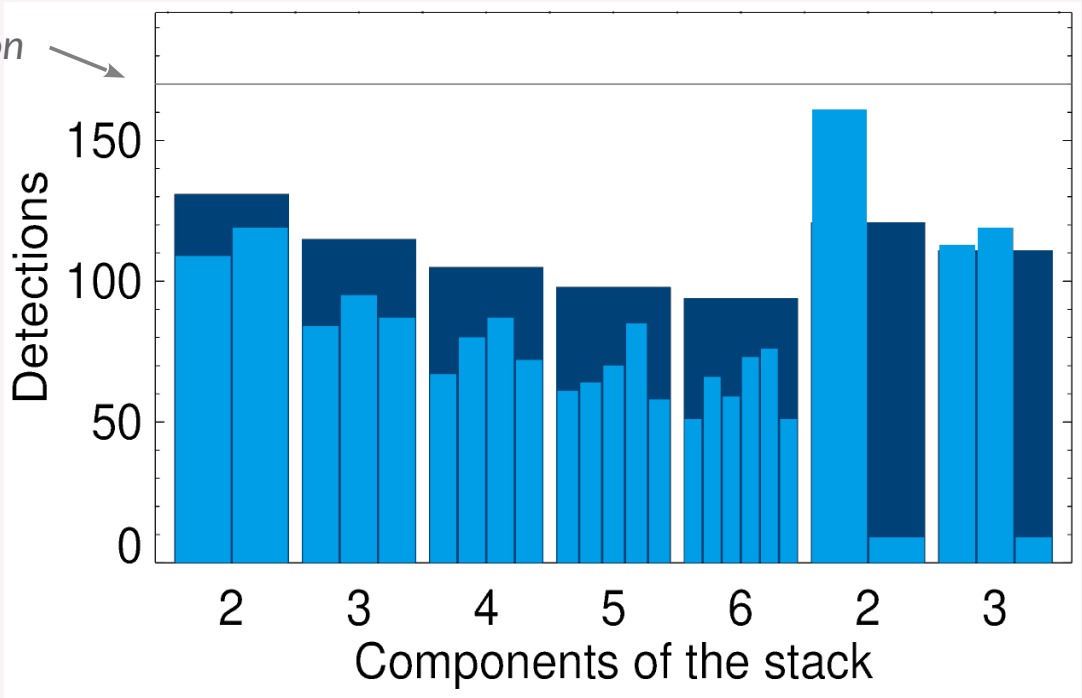

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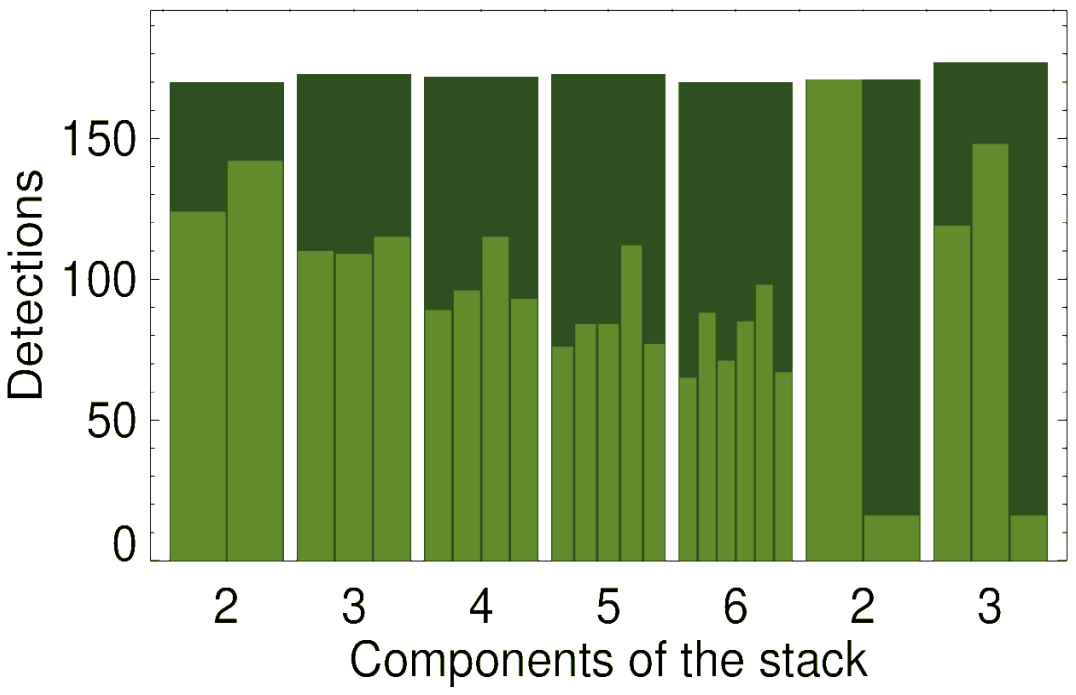
ARTIFICIALLY SPLIT OBSERVATIONS: SPECTRAL MODE

- Test: split >100ks observations and run source detection on snippets:

Stacks better than single and similar to un-interrupted,
for few and for many interruptions.



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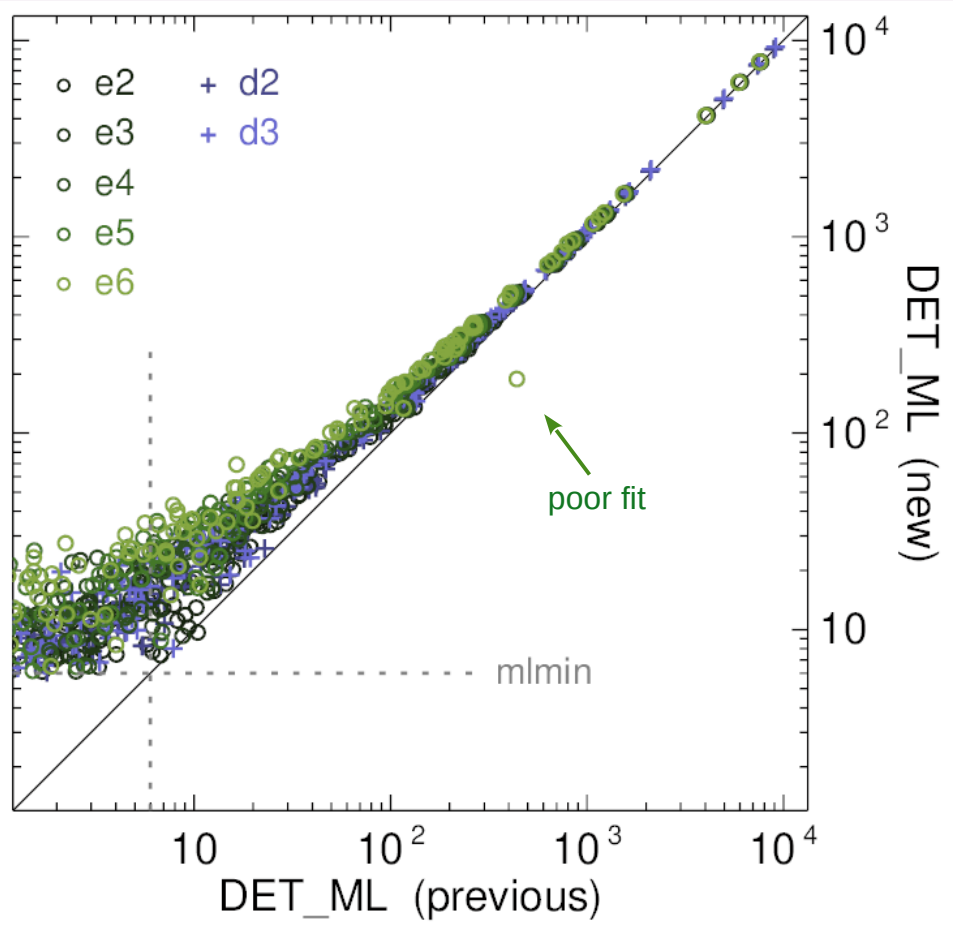
ARTIFICIALLY SPLIT OBSERVATIONS: SENSITIVITY



Higher detection likelihoods with the spectral than with the rates mode

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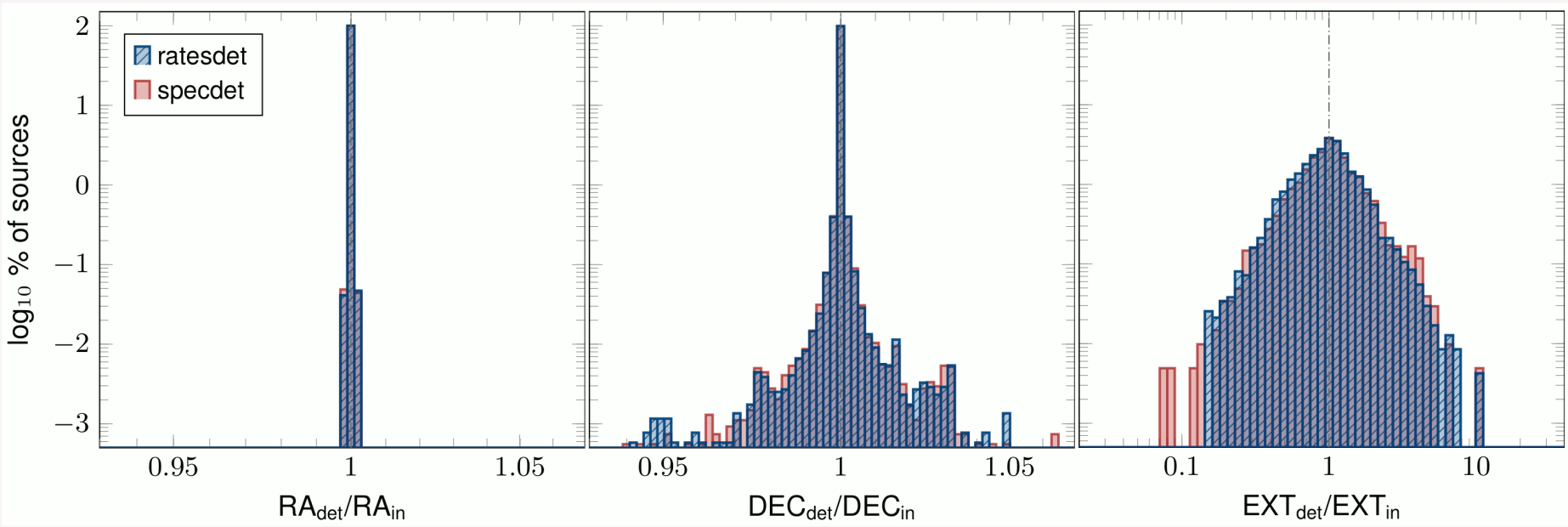
PARAMETER TESTS WITH RANDOMISED IMAGES

- Poisson randomised PSFs of input sources + background maps
- Positions and extent fit very well



Detected / input source parameters (logarithmic scale)

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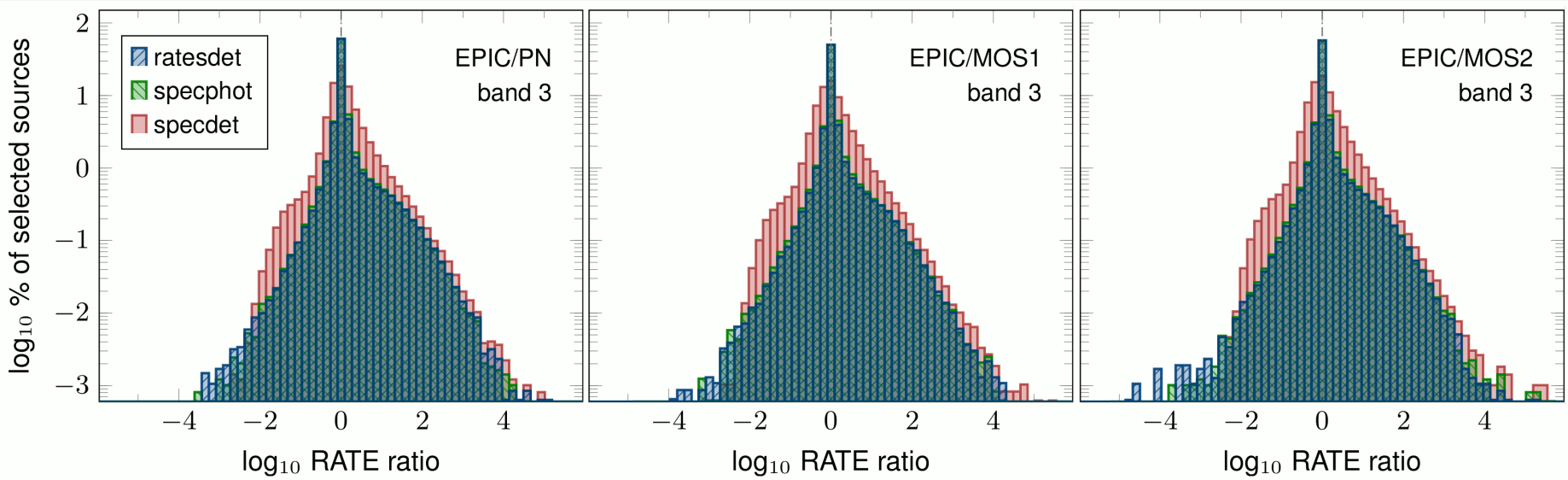
PARAMETER TESTS WITH RANDOMISED IMAGES

- Count rates fit very well in rates mode and in PSF photometry
- Expected deviations of count rates derived from coupled fluxes

  → improvements over the rates mode works best for sources with power-law spectra



Detected / input count rates (logarithmic scale)

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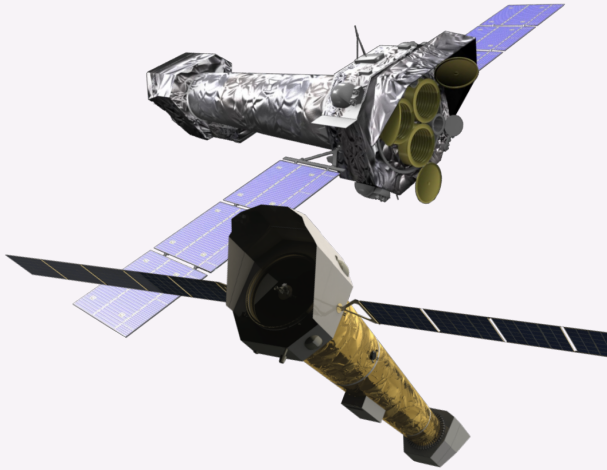
SUMMARY – AN ALTERNATIVE DETECTION MODE

- new source-detection mode for XMM-Newton … and future missions …
  - alternative to current detection mode
  - coupling fluxes over instruments and observations
  - subsequent PSF photometry and variability assessment



- development and validation in progress
  - higher sensitivity achieved
  - promising in particular for stacked source detection
  - proto-catalogues and Monte-Carlo simulations: talk by Adriana Mancini Pires

- envisaged for the next generation of XMM-Newton source catalogues

  ↪ 5XMM (2025)

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