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# AHEAD2020 WP14

## Application of MSVST to X-ray source detection



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# X-ray source detection: beyond 2D

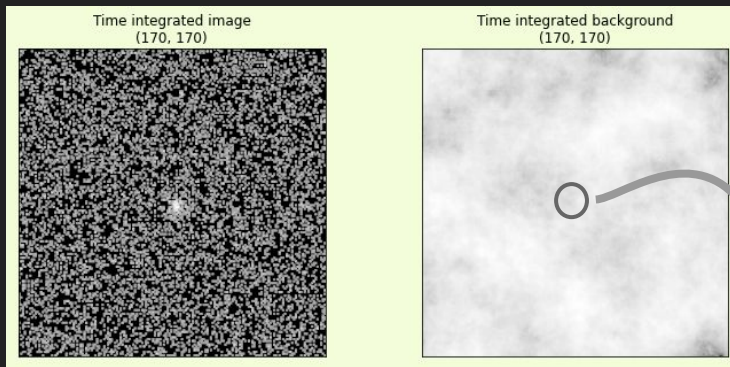
- Exploring how the inclusion of energy/time information can improve source detection.
- We focus on the **time domain**:  
Improving detection of **transient** sources.
- Algorithm: **MSVST 2D+1D & Bayesian Blocks**
- XMM-Newton **simulations** for testing.

# MSVST for X-ray source detection

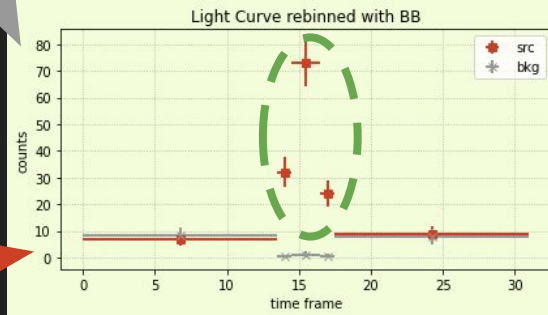
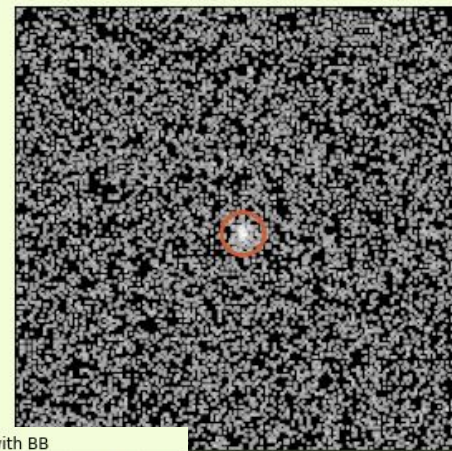
- MultiScale Variance Stabilization Transform (Stark et al. 2009).
- 2D+1D **denoising** algorithm based on wavelets.
- Two key ideas:
  - **2D + 1D:**
    - Disentangle spacial and time/energy dimensions.
    - Apply IUWT to 2D image, and then 1D IUWT to all wavelet coefficients.
  - **Variance stabilization:**
    - Transform poisson noise to gaussian noise.
    - Allows to apply “simple” thresholding for denoising.

# MSVST for X-ray source detection

## Light curves using Bayesian Blocks

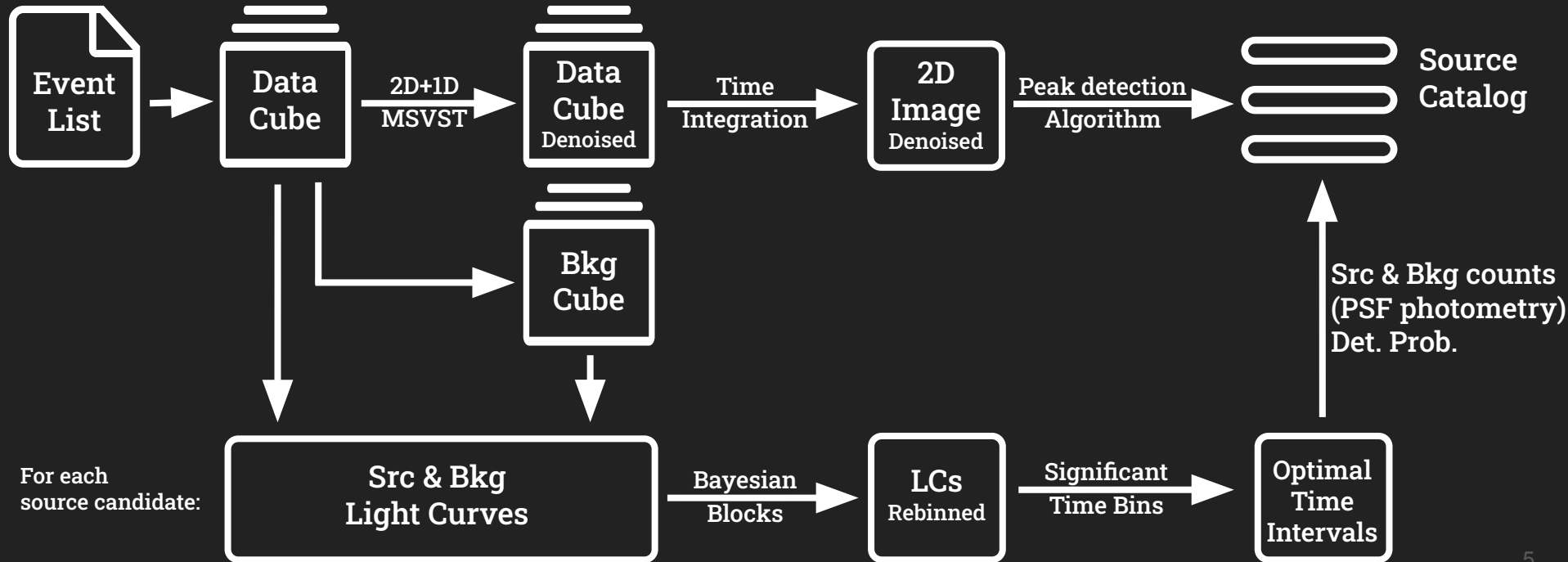


2D original image + time-filtered detected sources (170, 170)



# X-Ray Source Detection in 3D

## 2D+1D MSVST + Bayesian Blocks



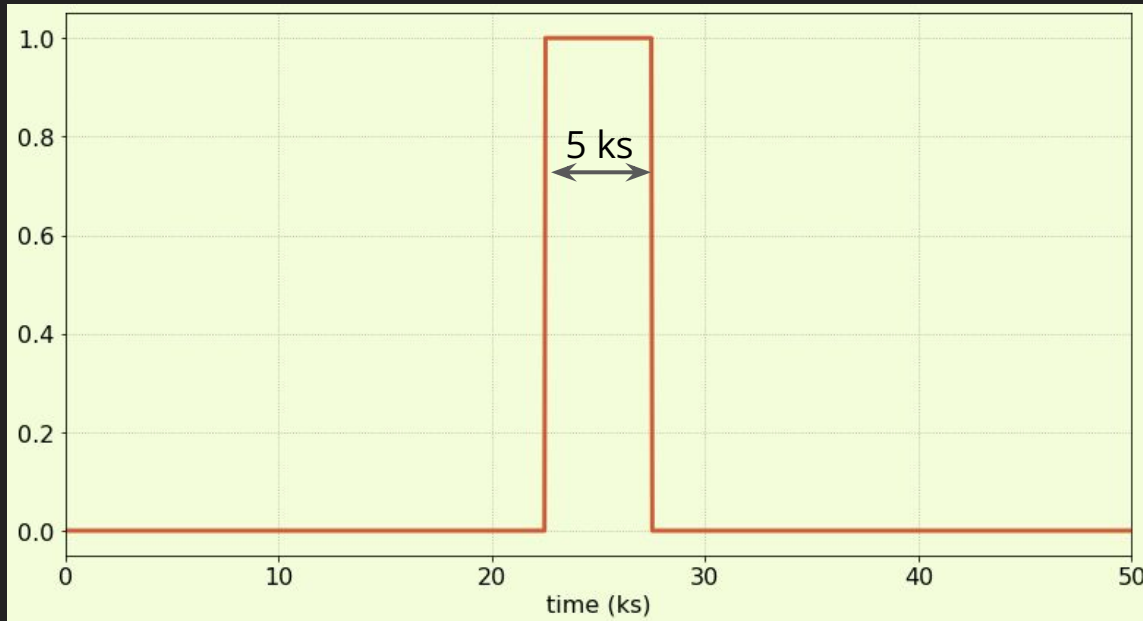


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**SIXTE**  
**simulations**

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# MSVST applied to XMM-Newton simulations SIXTE simulations of a transient source

EPIC-PN 50ks observation; constant background + transient source



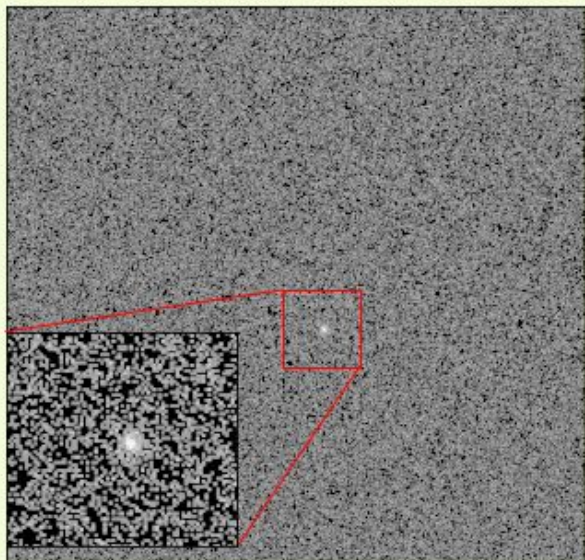
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# MSVST applied to XMM-Newton simulations

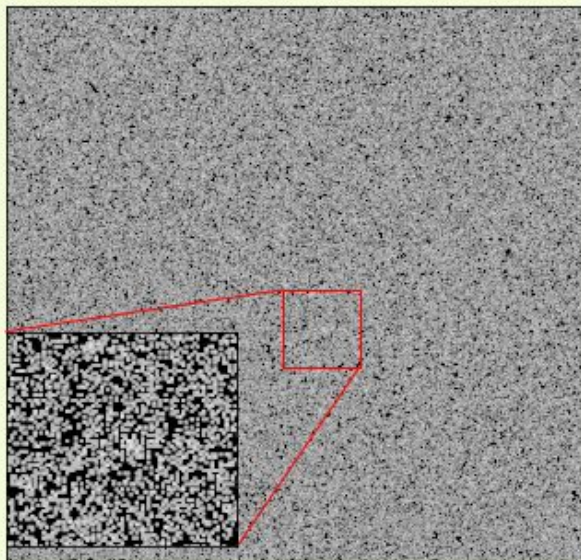
## SIXTE simulations of transient sources

EPIC-PN 50ks observation; constant background + transient source

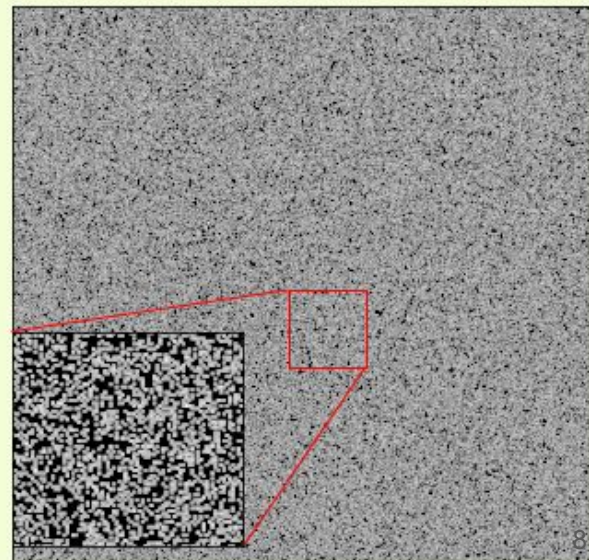
$F_X = 10^{-12}$  c.g.s.; S/B  $\sim 2.5$   
(574, 598)



$F_X = 10^{-13}$  c.g.s.; S/B  $\sim 1.3$   
(574, 598)



$F_X = 10^{-14}$  c.g.s.; S/B  $\sim 1.0$   
(574, 598)

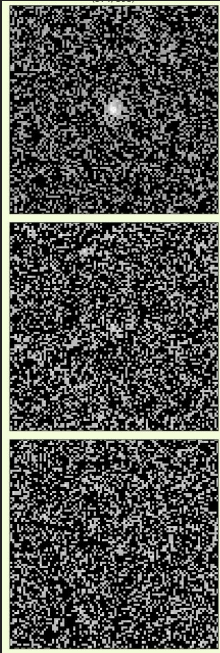




# MSVST applied to XMM-Newton simulations

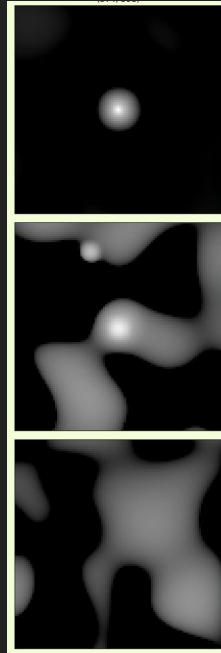
## Denoised images: 2D vs 2D+1D MSVST

Original image



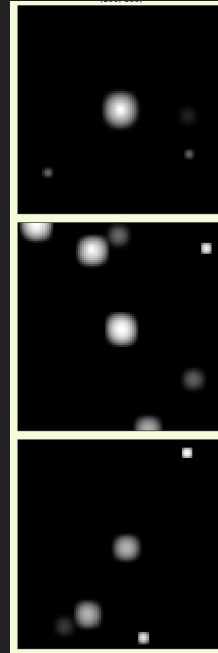
Data cube  
32 time frames

2D MSVST



min\_scalexy = 1  
max\_scalexy = 4  
**sigma\_level = 4**

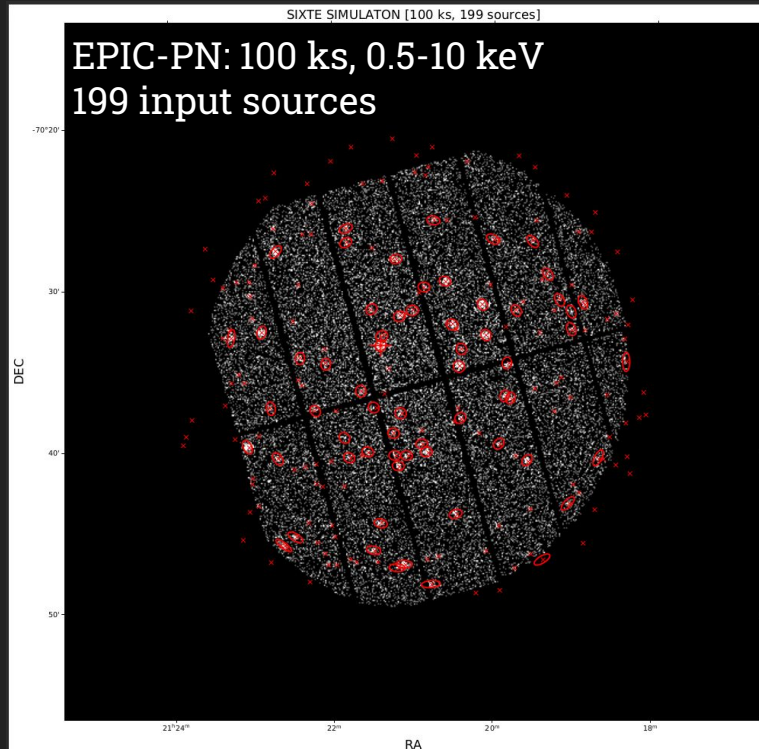
2D+1D MSVST



min\_scalexy = 1  
max\_scalexy = 4  
min\_scalez = 1  
max\_scalez = 5  
**sigma\_level = 5**

# MSVST applied to XMM-Newton simulations

## More realistic SIXTE simulations



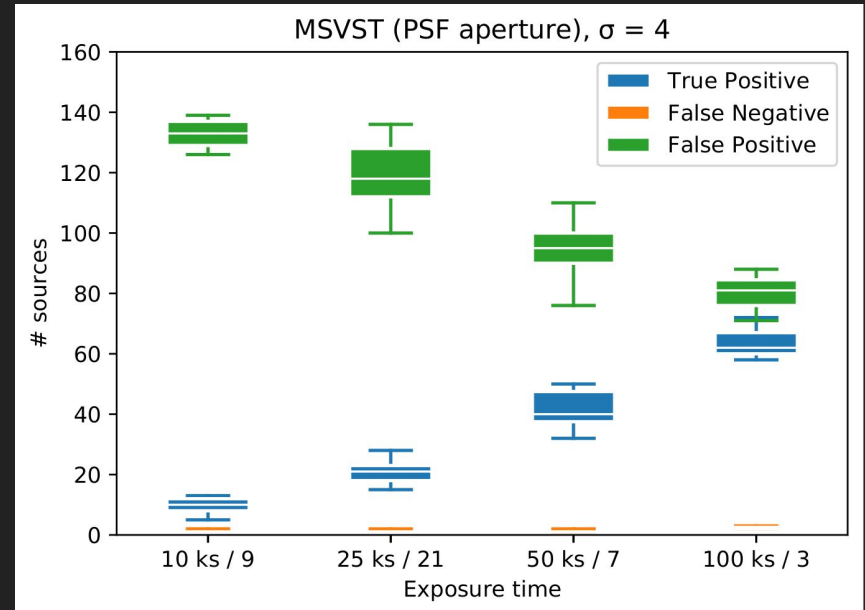
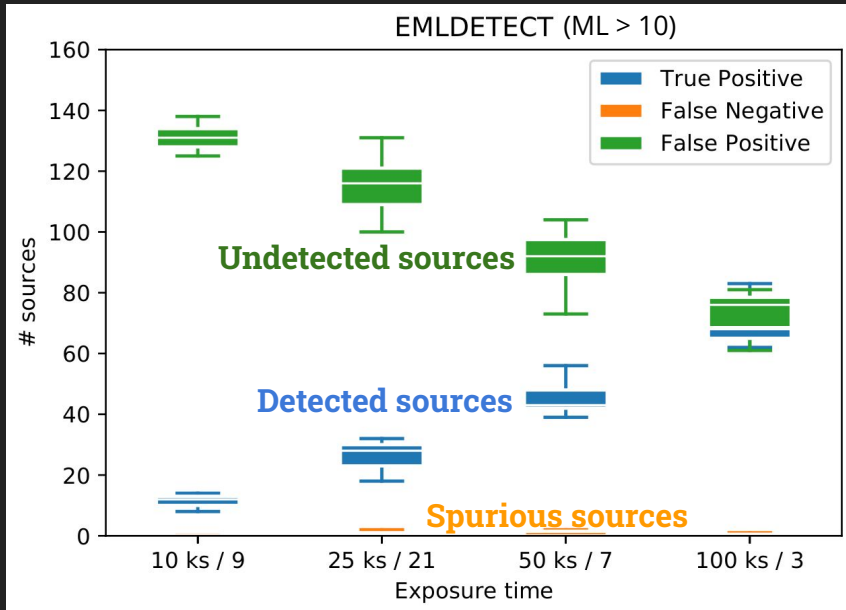
40 SIXTE simulations for XMM-Newton observations:

- Replicate geometry of EPIC-PN detector.
- Vignetting effects included.
- Random orientation of the detector.
- Exposure times: 10ks, 25ks, 50ks, 100ks.
- Sources randomly distributed in the FoV.
- Source flux distribution following an scaled logN-logS.
- Astrophysical background + particle background.

Data analyzed using SAS-EMLDetect  
and our 2D+1D MSVST algorithm.

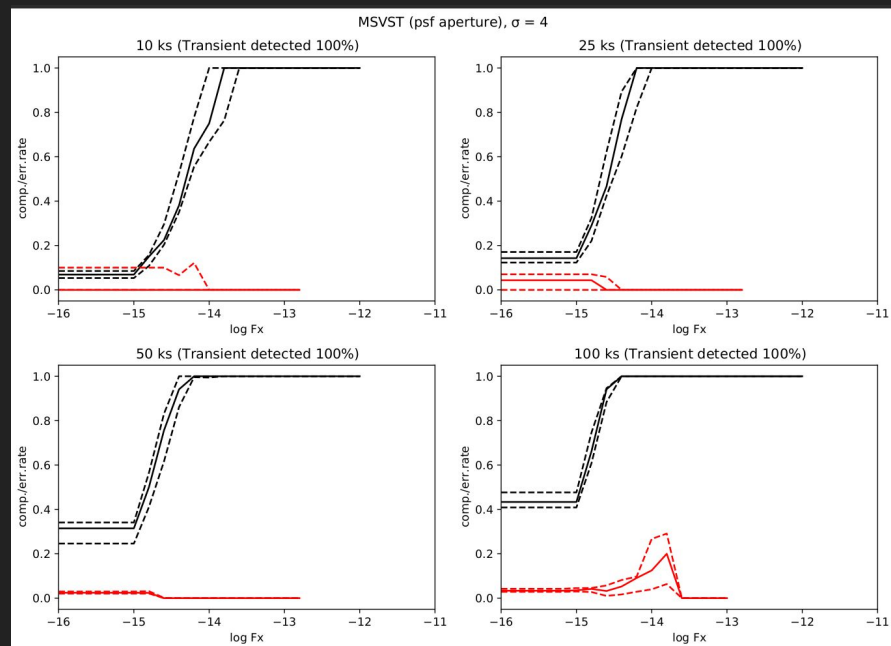
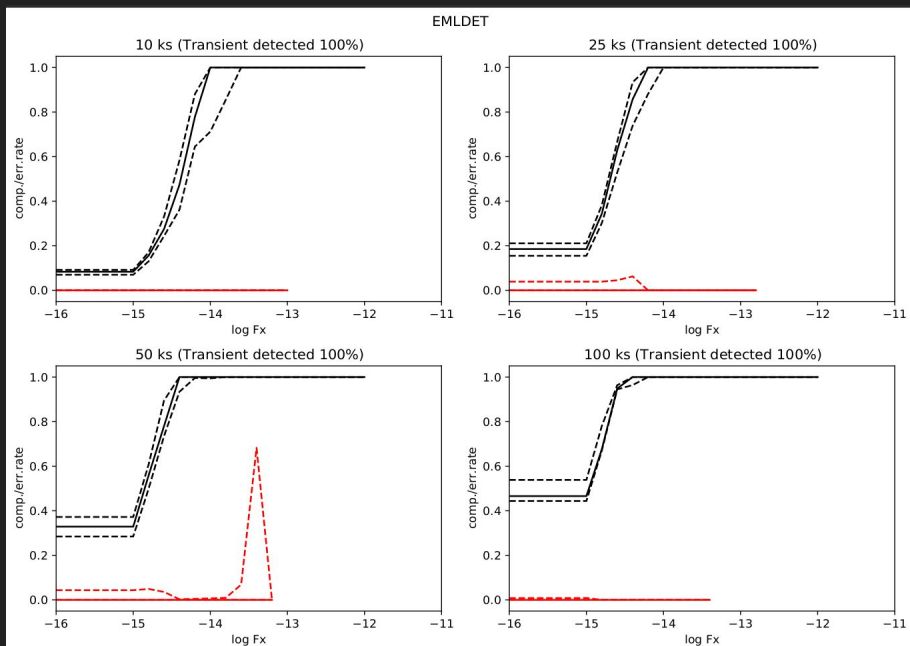
# MSVST applied to XMM-Newton simulations

## Comparison with SAS-EMLDET



# MSVST applied to XMM-Newton simulations

## Comparison with SAS-EMLDET



# Summary & Future Work

- We developed a **functional** 3D source detection algorithm with **performance similar to EMLDET** for constant sources.
- Better understanding and caveats in the time domain:
  - Increase statistics for comparison with EMLDET.
  - Study completeness and spurious rate for transient sources.
  - Effects of a time-variable background.
- Application to real XMM-Newton data: comparison with EXTraS (De Luca et al. 2021).
- Explore the capabilities of 2D+1D MSVST in the energy domain.