

Early results on STIX imaging

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n|w

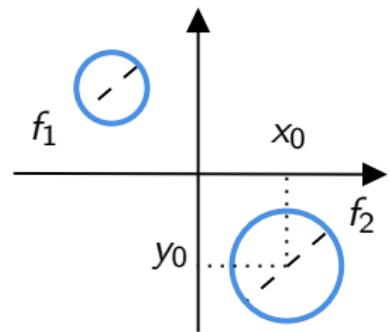
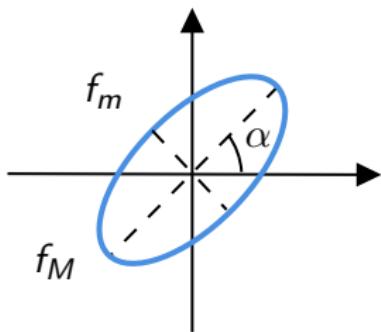
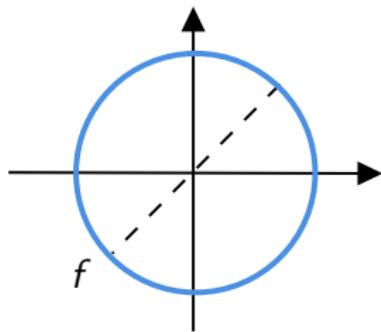
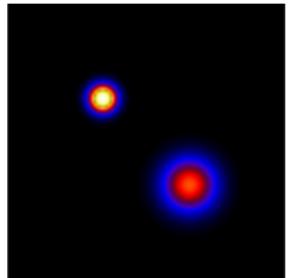
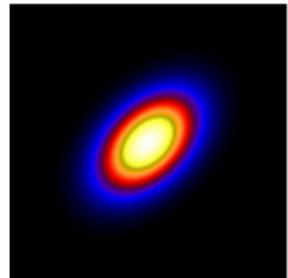
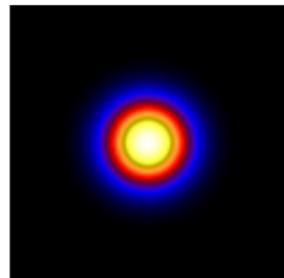
**Visibility phases are not calibrated yet
(they will be available soon)**

Problem: the position of the source can not be recovered from amplitudes only

Approach:

- ▶ parametric source shapes
- ▶ forward-fitting methods for retrieving the parameters

Parametric shapes (Massa, P., et al. (2021))



$$\theta = (\phi, f)$$

$$\theta = (\phi, f_M, f_m, \alpha)$$

$$\theta = (x_0, y_0, \phi_1, f_1, \phi_2, f_2)$$

Particle Swarm Optimization (PSO)

Stochastic optimization method
for solving

$$\arg \min_{\theta \in \mathcal{D}} \chi^2(\theta)$$

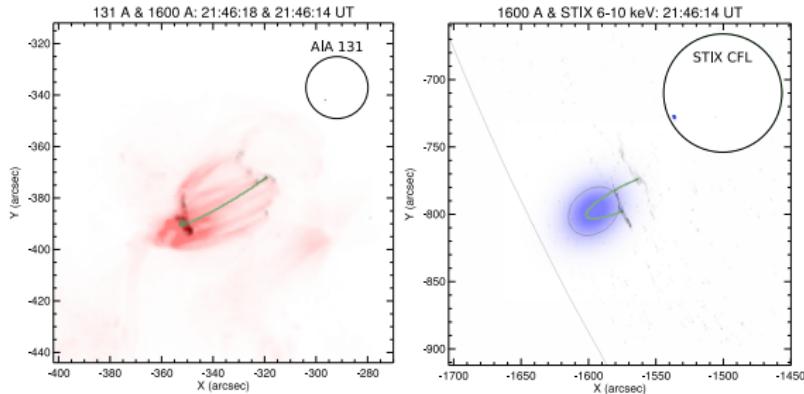
Sequential Monte Carlo (SMC)¹

Finds an approximation of the
posterior distribution $p(\theta|A)$

June 7, 2020 event (Battaglia, A. F., et al. (2021))

Time interval: 21:45:44 - 21:46:44 (GOES class B6)

PSO reconstruction: Gaussian elliptical source

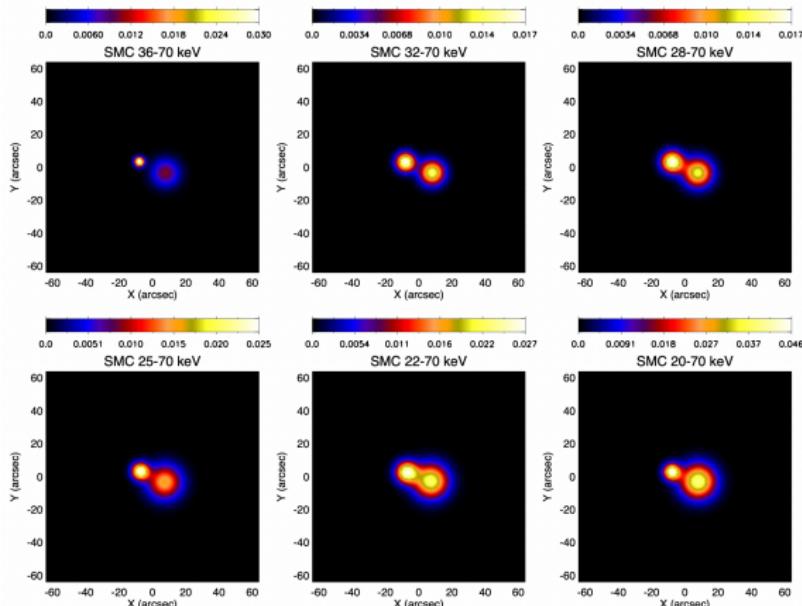


Flux (counts s^{-1} keV $^{-1}$)	3.1 ± 0.2
FWHM max (arcsec)	35.5 ± 5.9
FWHM min (arcsec)	27.5 ± 4.1
Orientation (degrees)	131 ± 38
χ^2	0.35

November 18, 2020 event (Massa, P., et al., (2021))

Time interval: 05:45:30 - 05:46:15 (GOES class > M9)

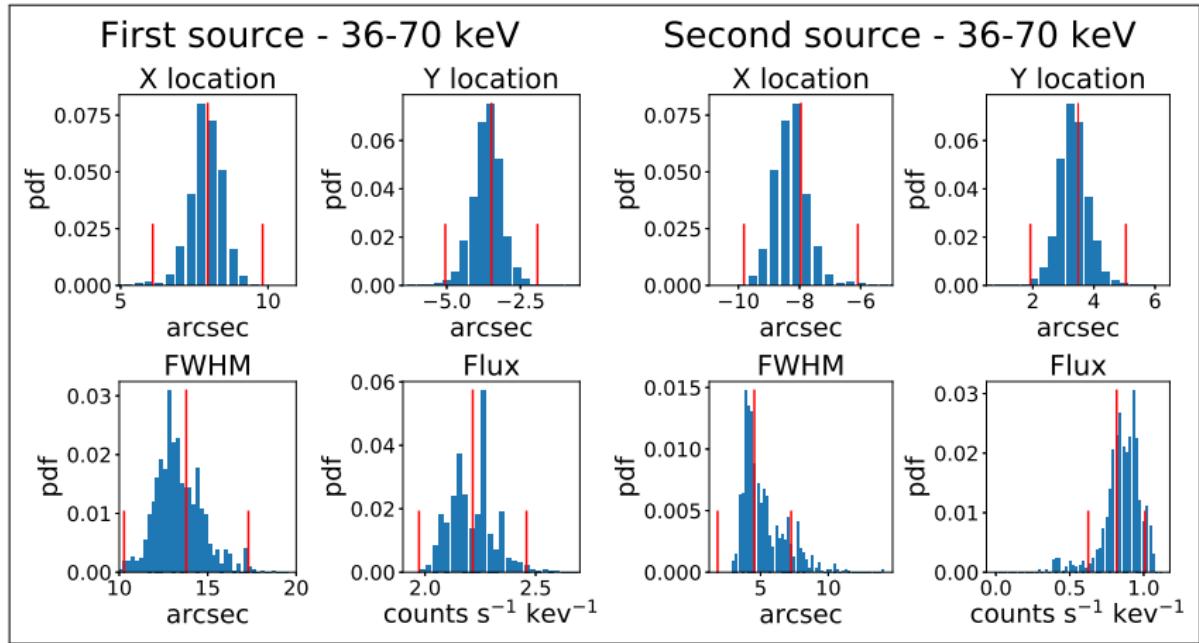
SMC reconstructions: double Gaussian circular source



Possible interpretation: nonthermal bremsstrahlung emission (left source), thermal emission with a nonthermal tail (right source)

November 18, 2020 event (Massa, P., et al., (2021))

SMC posterior distributions



References

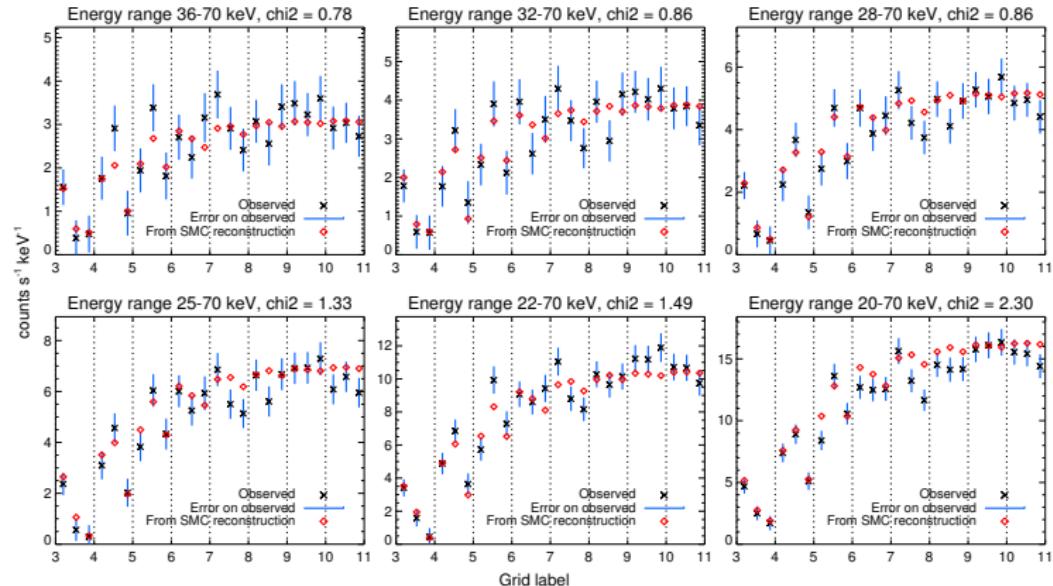
-  Krucker, S., et al., *The Spectrometer/Telescope for Imaging X-rays (STIX)*, *Astronomy & Astrophysics*, 642 (2020)
-  Massa, P., et al., *Imaging from STIX visibility amplitudes*, submitted to *Astronomy & Astrophysics* (2021)
-  Sciacchitano, F., et al., *Identification of multiple hard X-ray sources in solar flares: A Bayesian analysis of the 2002 February 20 event*, *The Astrophysical Journal*, 862 (2018)
-  Battaglia, A. F. et al., *STIX X-ray microflare observations during the Solar Orbiter commissioning phase*, to appear on *Astronomy & Astrophysics* (2021)

Do you want to try it out? Find the code at
https://github.com/sgarbarino/Sparse_Bayesian_Imaging_RHESSI/tree/2021_rhessi_workshop_TUTORIAL

Thank you for the attention!

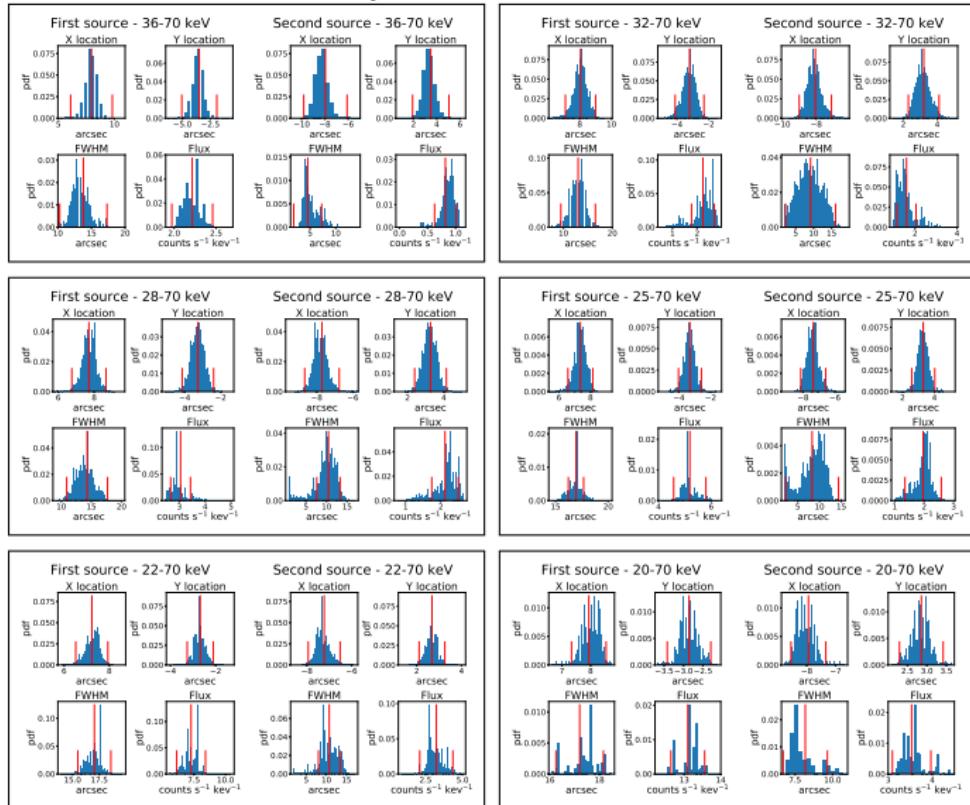
November 18, 2020 event - 1 (Massa, P., et al., (2021))

SMC reconstructions: double Gaussian circular source



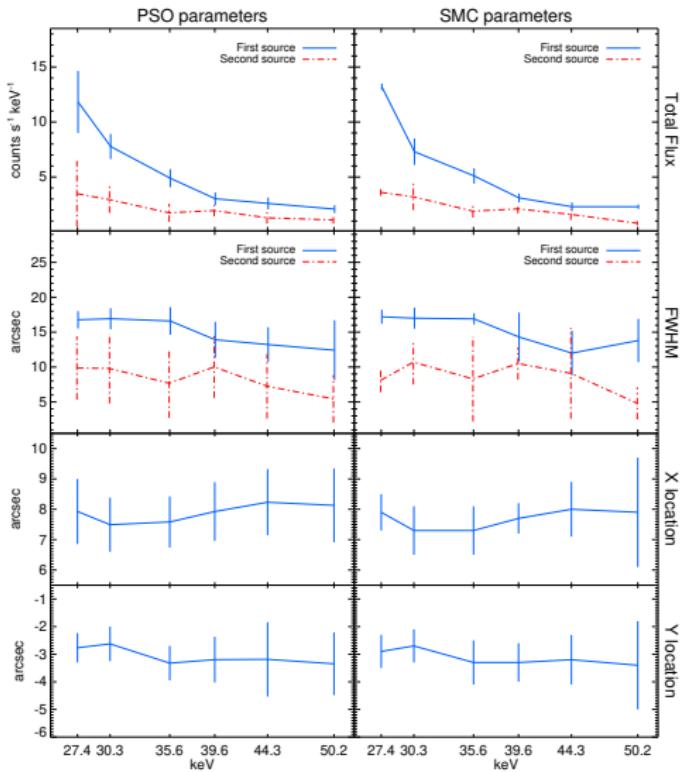
November 18, 2020 event - 1 (Massa, P., et al., (2021))

SMC posterior distributions



November 18, 2020 event - 1 (Massa, P., et al., (2021))

PSO and SMC comparison

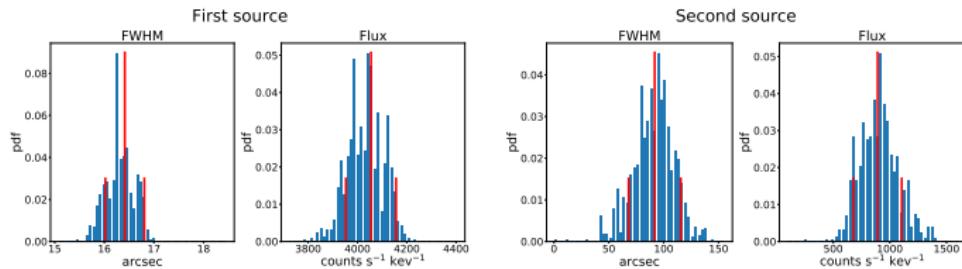
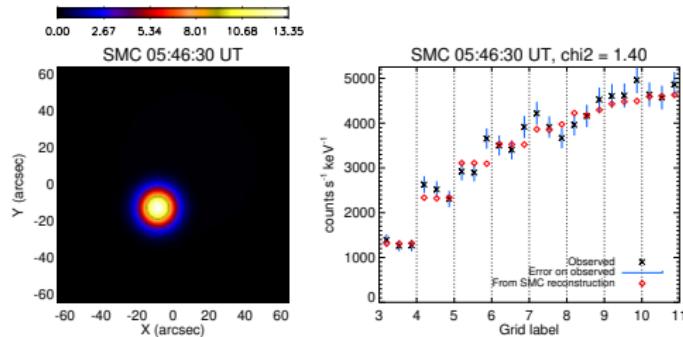


November 18, 2020 event - 2 (Massa, P., et al., (2021))

Time interval: from 05:46:30 to 05:46:31 (1 sec)

Energy range: 7–12 keV

SMC reconstruction: double Gaussian circular source



compact source + faint halo

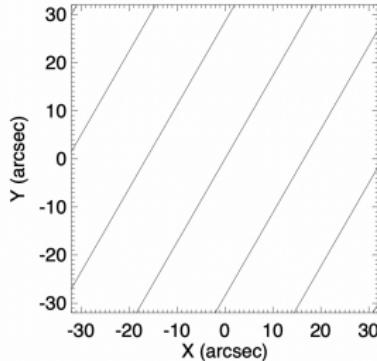
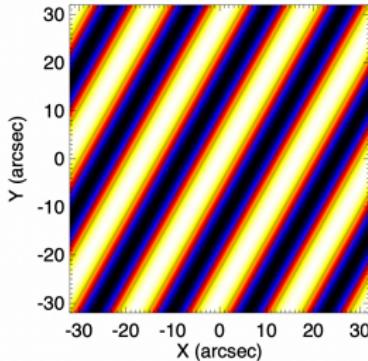
Visibility phase calibration

The backprojection of a single visibility is a sinusoidal wave

$$\varphi(x, y) = A \cos(2\pi(xu + yv) - \Phi) ,$$

where

- ▶ A is the visibility amplitude
- ▶ Φ is the visibility phase
- ▶ (u, v) is the frequency sampled by the subcollimator

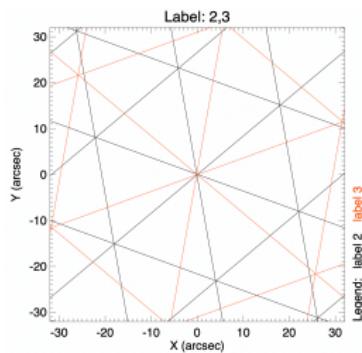
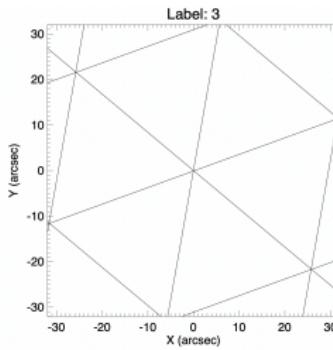
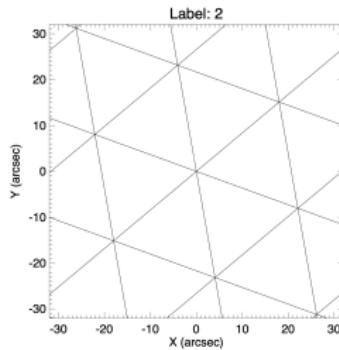


Visibility phase calibration

Assumptions:

- ▶ the source is unresolved (point source)
- ▶ the phases are well calibrated

The lines corresponding to subcollimators with the same angular resolution form triangles



Simulated point source in $(0, 0)$

Visibility phase calibration

Goal: correct systematic error in the visibility phases due to a modification of STIX hardware parameters:

- ▶ relative orientation of rear grid and detectors
- ▶ relative orientation of front and rear grids
- ▶ relative shift of the rear grid and detectors

Approach: optimize the *closure phases* (signed sum of three phases equal to $2\pi k$, $k = \dots, -1, 0, 1, \dots$)

Check: use the imaging method for monitoring the phase calibration status

Still work in progress!