STIX tutorial - Amplitude imaging

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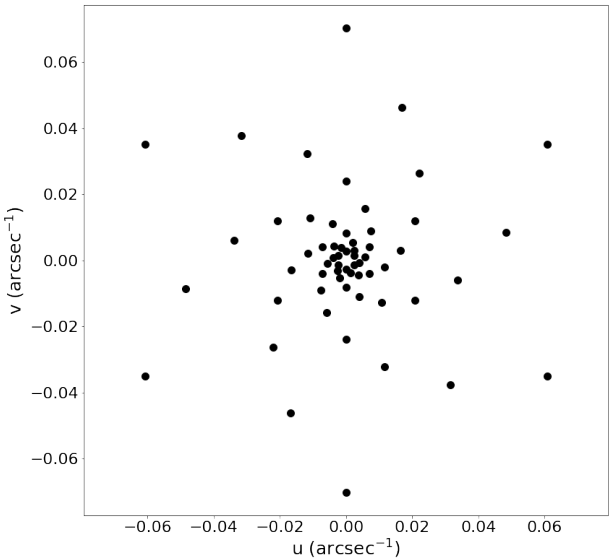
STIX imaging problem: overview

- STIX measures $V_1, \ldots, V_{30}$ visibilities



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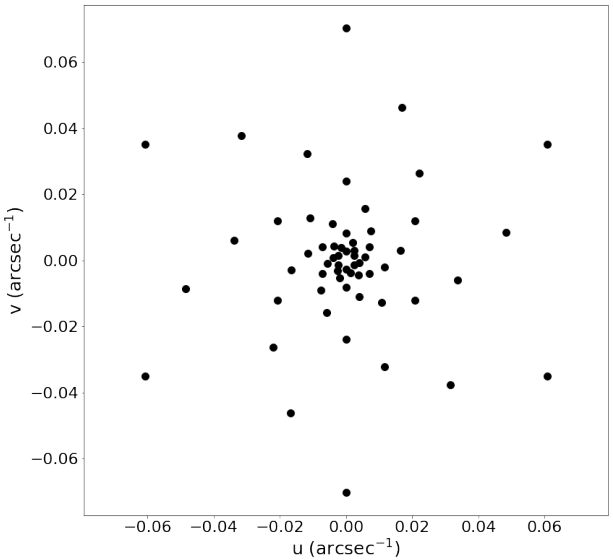
- The imaging problem is

$$\mathcal{F}\varphi = V$$

where

- $\mathcal{F}$ is the Fourier transform
- φ is the image of the X-ray emission
- $V = (V_1, \ldots, V_{30})$



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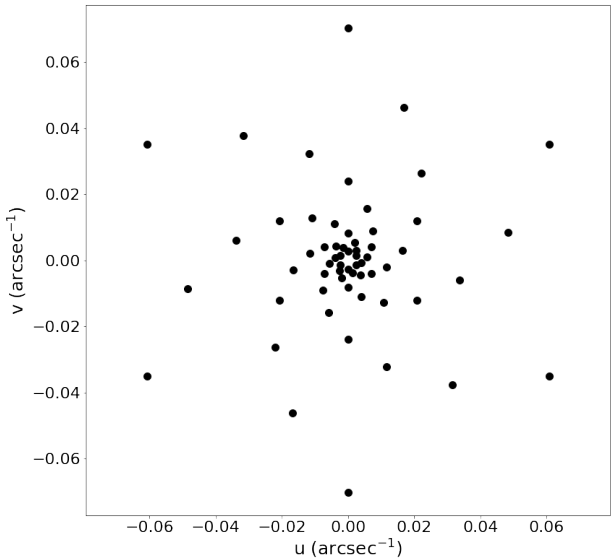

Algorithms for calibrated data (RHESSI legacy)[1]:

- backprojection
- CLEAN
- MEM_GE
- VIS_FWDFIT
- Expectation Maximization (count-based)
- uv_smooth
- VIS_CS and VIS_WV
- Bayes

[1] https://hesperia.gsfc.nasa.gov/rhessi3/software/imaging-software/image-algorithm-summary/index.html

Amplitude imaging (Massa., P., et al., (2021))

The visibility amplitudes only are available for imaging (visibility phases will come soon)

Imaging problem from visibility amplitudes:

$$|\mathcal{F}\varphi| = A \ ,$$

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No phases $\Rightarrow$ no information on the absolute position

Amplitudes $\Rightarrow$ information on dimension, orientation and relative position

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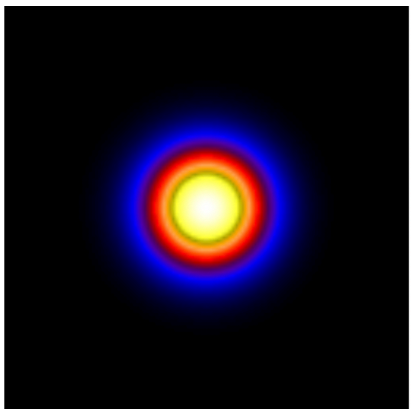
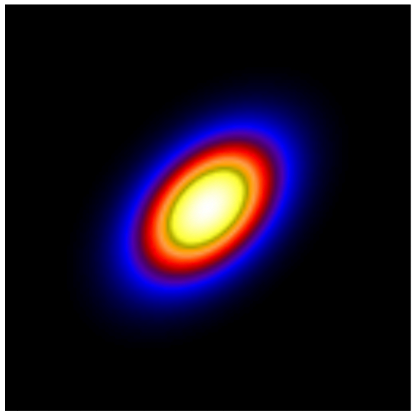
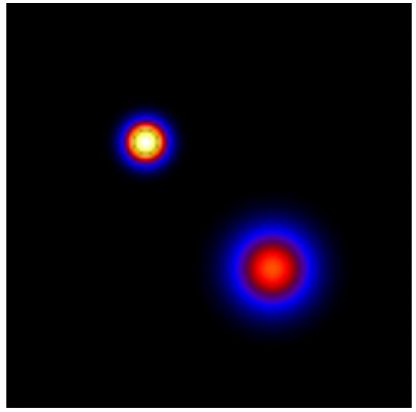
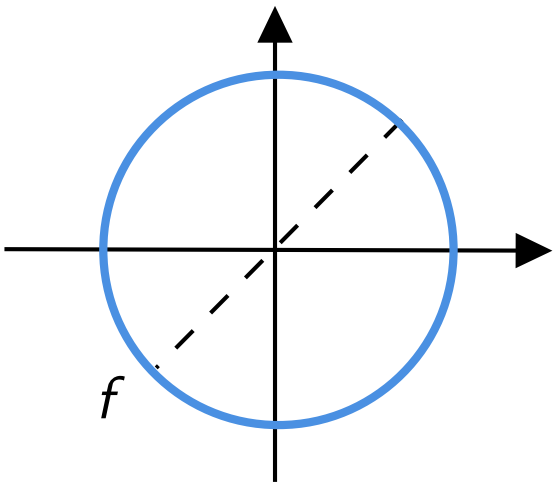
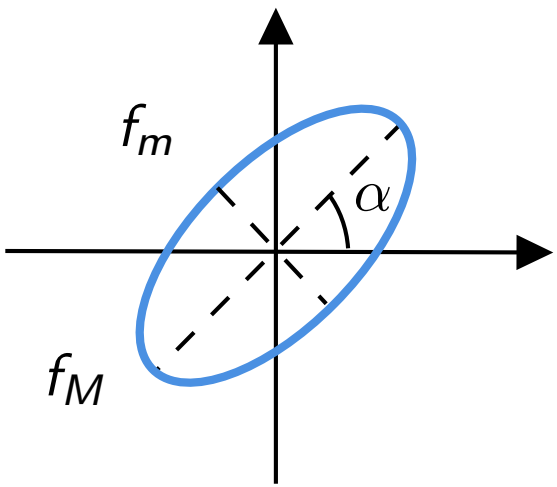
Approach: parametrized source shapes

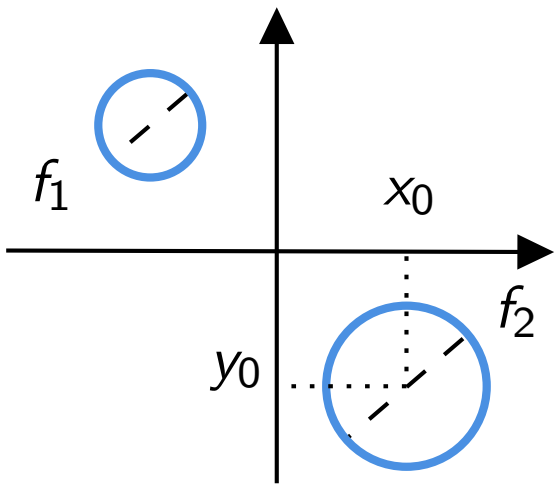












$\theta = (\phi, f)$

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

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

Particle Swarm Optimization (PSO) (Massa., P., et al., (2021))

How it works:

- choose the configuration (circular Gaussian, elliptical Gaussian, double circular Gaussian)
- find with PSO the parameters θ^* such that

$$\theta^* = \arg\min_{\theta} \chi^2(\theta) \ ,$$

where

$$\chi^2(\theta) = \sum_i \frac{(|(\mathcal{F}\varphi(\theta))_i| - A_i)^2}{\sigma_i^2}$$

- estimate the parameter uncertainties with the *confidence strip* approach (optional)

Sequential Monte Carlo (SMC)[2] (Massa., P., et al., (2021))

How it works:

- choose the configuration (circular Gaussian, elliptical Gaussian, double circular Gaussian)
- approximate with SMC the probability distribution $p(\theta|A)$
- compute θ^* as the mean value of the probability distribution
- compute the parameter uncertainties as the standard deviation of the probability distribution

[2] Sciacchitano, F., et al. (2018)

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!