RHESSI X – Annapolis August 1-6, 2010

Imaging with visibilities: uv_smooth

Anna Maria Massone CNR-SPIN, Genova, Italy

annamaria.massone@cnr.it



Consiglio Nazionale delle Ricerche

Imaging with RHESSI visibilities

The nine Rotating Modulation Collimators generate Fourier components (real and imaginary parts) in series of nine circles in Fourier space:

$$V(u,v;\varepsilon) = \iint I(x,y;\varepsilon) e^{2\pi i (ux+vy)} dx dy$$







The idea of *uv_smooth*

uv_smooth is an imaging algorithm for hard X-ray imaging of solar flares using interpolated visibilities

(massone, emslie, hurford, prato, kontar and piana, astrophys. j. 2009)

 if R is the biggest collimator radius in the uv-plane, estimate the visibilities inside the circle of radius R by means of an interpolation routine





2. using these uniformly-spaced visibility values in a FFT-image reconstruction algorithm AND the imposition of a **positivity constraint** on the image produces images in which many of the undesirable sidelobes associated with sparse (*u; v*) sampling are suppressed extrapolation effects

uv_smooth in the SSW gui

🗐 Imaging - RHESSI Data Analysis Dev. Version, 27-Aug-2009 11:23 📃 🗖 🔀
IMAGING (* - changing these parameters forces reprocessing and takes longer)
Select Input: Raw Data 20-Feb-2002 11:06:02.000 to 11:06:34.000 Change Selected Time Range: 20-Feb-2002 11:06:02 to 20-Feb-2002 11:06:34 Flare 2022003: 20-Feb-2002 11:04:08.000 to 11:12:20.000 Peak: 11:06:18.000, 656.000 c/s
× 1 Image Time Interval: 20-Feb-2002 11:06:02.000 to 11:06:34.000 ▼ Change 4s at peak
* 1 Energy Band (keV): 10.0 to 15.0 Change Binning Code: None Show Binning Codes
Collimators and Detector Front/Rear Segments Selected: 1FR, 2FR, 3FR, 4FR, 5FR, 6FR, 7FR, 8FR, 9FR Automatic Time Bin Calculation: Enabled Digital Quality: 0.95 Pixel Size (arcsec): 1.0 x 1.0 Image Dimensions (pixels): 128 x 128 Offset of Map Center from Sun Center (arcsec): X: 907.00 Y: 258.35 Image Size = 128 x 128 arcsec X range = 843 to 971 arcsec
Karage Algorithm: UV_Smooth ▼ Set parameters Set visibility params Mark clean boxes
Flatfield: Enabled Clean Phase Stacker: Disabled Cull: Enabled (Fraction: 0.50) Weighting: Natural Pixon Prosect): 0.00 Local Average: Disabled Change Variable Flux Conet MEM NJIT cimation Correction: Front Rate-based BProj: Enabled Change
Send Image(s) x: V Smooth rrs rile Show: ✓ Progress Bar Verbose Images
Make/Plot Image(s) Plot GOES Write FITS File Display -> Movie Write Script ->
Refresh Reset to Defaults Set Params Manually Help Close

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Electron visibilities and electron maps

Anna Maria Massone CNR-SPIN, Genova, Italy annamaria.massone@cnr.it



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From photon to electron visibilities

• Photon visibility definition:

$$V(u,v;\varepsilon) = \iint I(x,y;\varepsilon) e^{2\pi i (ux+vy)} dx dy$$

• Bremsstrahlung equation:

$$I(x, y; \varepsilon) = \frac{a^2}{4\pi R^2} \int_{\varepsilon}^{\infty} \overline{F}(x, y; E) Q(\varepsilon, E) dE$$

• Electron visibility definition:

$$W(u,v;E) \coloneqq \frac{a^2}{4\pi R^2} \iint \overline{F}(x,y;E) e^{2\pi i (ux+vy)} dx dy$$

• Bremsstrahlung equation for visibilities

$$V(u,v;\varepsilon) = \int_{\varepsilon}^{\infty} W(u,v;E)Q(\varepsilon,E)dE$$

From photon to electron visibilities

$$V(u,v;\varepsilon) = \int_{\varepsilon}^{\infty} W(u,v;E)Q(\varepsilon,E)dE$$

The relation between the **measured photon visibilities** and the **electron visibilities** is described by a Volterra integral equation of the first kind

Visibility inversion problem: determine the electron visibilities, W(u,v;E), from the observed count visibilities $V(u,v;\varepsilon)$

Visibility information in photon space may, through a (regularized) spectral inversion technique, be converted to visibility information in the *electron* domain.

Algorithm for electron image reconstruction:

1. for each (u,v) pair solve

$$V(u,v;\varepsilon) = \int_{\varepsilon}^{\infty} W(u,v;E)Q(\varepsilon,E)dE$$

by means of Tikhonov regularization algorithm (which smoothes along the energy direction)

2. for each E solve

$$W(u,v;E) = \frac{a^2}{4\pi R^2} \iint \overline{F}(x,y;E) e^{2\pi i (ux+vy)} dxdy$$

by means of a Fourier-based imaging algorithm (which reduces ringing effects by imposing appropriate constraints)











From electron visibilities to electron maps





Visibility-based electron maps

Imaging from visibilities: MEM



10-14 keV

14-18 keV 1

18-22 keV

22-26 keV

26-30 keV



30-34 keV 34-38 keV 38-42 keV 42-46 keV 46-50 keV

Visibility-based electron maps

Imaging from visibilities: MEM



50-54 keV

54-58 keV

58-62 keV

62-66 keV

66-70 keV



70-74 keV 74-78 keV 78-82 keV 82-86 keV 86-90 keV



10-14 keV 14-18 keV 18-22 keV 22-26 keV 26-30 keV





30-34 keV 34-38 keV 38-42 keV 42-46 keV 46-50 keV











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APPLICABILITY CONDITIONS

This software is an effective imaging spectroscopy procedure, i.e. it provides electron visibility cubes from photon visibility cubes. Therefore:

- you need count visibilities at many count energies
- you need uniform sampling of the count energies (optimal energy bins 2-4 keV)
- the output electron energies are uniformly sampled with the same bin (but you can resample by combining visibilities)
- you will have more output electron energies than input count energies
- the count visibilities are combined before inversion, then the electron visibility are combined too (i.e. u>0)
- the visibility spectral inversion procedure may fail for some u,v points
 you may have less electron visibility spectra than count visibility spectra