# uv\_smooth: Basic Principles and Usage

## The RHESSI imaging concept according to uv\_smooth

- RHESSI rotating modulation collimators generate Fourier components (real and imaginary parts) in series of circles in the uv-plane;
- making images with uv\_smooth consists of:
  - 1. interpolating the visibilities in the uv-plane,
  - 2. reconstructing the image of the source by means of a fast Fourier transform inversion,
  - 3. reducing the ringing effects by imposing a positivity constraint.

<u>Remark:</u> in uv\_smooth, items 2. and 3. are performed in one shot, by means of an iterative algorithm.

# **Interpolation (Figure 1)**

- RHESSI samples the uv-plane in circles whose radii are signatures of the collimators;
- a real and an imaginary smooth visibility surfaces are generated by applying a thin-plate spline algorithm

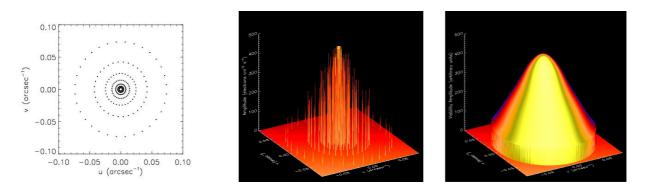


Figure 1. Left: how RHESSI samples the uv-plane; middle: visibility amplitudes; right: visibility amplitude smooth surface provided by spline interpolation

## Image reconstruction and ringing reduction (Figure 2)

- The fast Fourier transform inversion of the visibility surface is performed iteratively, by means of a successive approximation scheme;
- at each iteration all negative pixels are set to zero, thus reducing ringing effects around the source image;
- the iteration is stopped when a  $\chi$ -squared criterion is fulfilled.

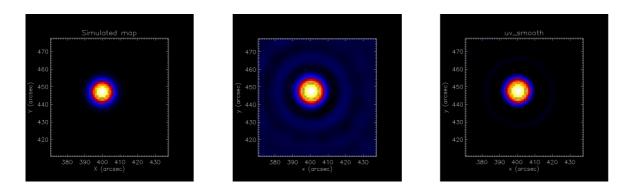


Figure 2. Left: original source; middle: Fourier transform inversion of the visibility smooth surface; right: ringing reduction by means of successive applications of the positivity constraint.

# Example: July 23 2002 (Figure 3)

- time interval: 00:29:10 00:30:19 UT
- collimators: 3 to 9

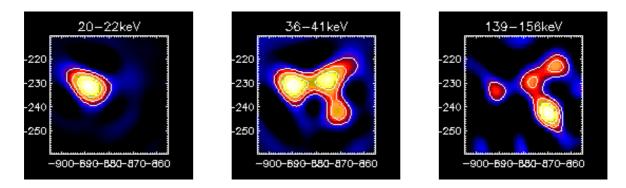


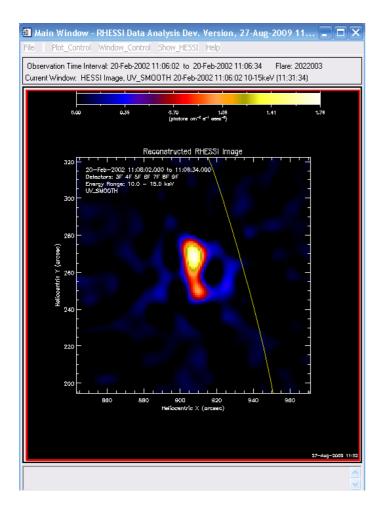
Figure 3. Left: energy channel: 20-22 keV; middle: energy channel: 36-41 keV; right: energy channel: 139-156 keV

### Current release of the software

- The gridding in the uv-plane is performed according to a cartesian sampling;
- Parameters in the GUI (Figure 4):
  - pixelsize: 1 arcsec;
  - image size: 128x128 or 64x64;
  - 'combine conjugates': disabled (uv\_smooth needs visibilities in all four quadrants of the uv-plane. If the user enable the 'combination' option, the software automatically ignores it);
  - $\circ$  detectors: any combination of detectors from 3 to 9.
- Output in the GUI (Figure 5):
  - reconstructed image (main window)
  - uv sampling (optional, if the flag 'Plot visibilities' in the 'Visibility options' window is enabled).

🗃 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         Chang           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	e
*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	I Visibility options
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	Edit outliers     and combine conjugates     Normalize     Maximum Chisquare:     1.00e+009     Plot visibilities
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         Y range = 194 to 322 arcsec       X	Output file: Browse
Kimage Algorithm: UV_Smooth      Set parameters Set visibility params Mark clean boxes	Reset to Defaults Cancel Accept
Flatfield: Enabled     Clean     Phase Stacker: Disabled     Cull: Enabled (Fraction: 0.50)       Weighting: Natural Forward Fit     arcsec): 0.00     Local Average: Disabled     Change       Variable Flux Corred MEM NJIT     simation Correction: Front     Rate-based BProj: Enabled     Change	
Send Image(s) to: VS Smooth FITS Pile Show: VProgress 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	

Figure 4. Input parameters in the imaging window.



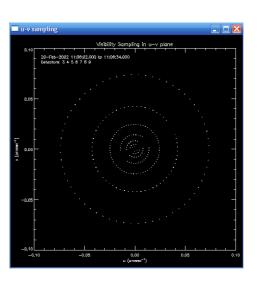


Figure 5. Output windows

### Reference

Massone A M, Emslie A G, Hurford G J, Prato M, Kontar E P and Piana Hard X-ray Imaging of Solar Flares using Interpolated Visibilities *Astrophysical Journal* 703 (2009) 2004-2016.