Measurement and Interpretation of X-ray Visibilities with RHESSI

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INTRODUCTION

- RHESSI uses 9 rotating modulation collimators (RMCs) to image solar flares at x-ray and gamma-ray energies.
- Each RMC consists of a pair of widely separated grids with equal, parallel slits in front of a detector.
- As the spacecraft rotates, imaging information is encoded as rapid time-variations of the detected flux.
- This poster describes two new approaches to converting the modulated time profiles to images.

DATA STACKING

WHAT IS IT?

- Data stacking is an adaptation of superimposed epoch analysis that makes RHESSI data from multiple rotations equivalent to that from a single rotation.
- Since spacecraft pointing variations makes the modulated light curves different in each 4 second rotation, simply averaging count rates from subsequent rotations does not usually work.
- Instead of superimposing data on the basis of time, data are combined on the basis of spacecraft roll angle and aspect phase (the component pointing direction orthogonal to the grid slits).

ADVANTAGES

- Improves image quality by eliminating statistical issues associated with large numbers (>>10^5) of sparsely populated time bins.
- Helps with background and flare-variability issues.
- Improves imaging speed.
- Makes long integrations possible (10's of minutes to days).
- Opens the way to using visibilities…

VISIBILITIES

WHAT ARE THEY?

Visibilities are calibrated measurements of Fourier components of the source distribution.

- They are measured at specific spatial frequencies, whose magnitude is 1 (the angular resolution of the collimator) and whose direction is perpendicular to the grid slits.
- Visibilities represent a compact, noise-free transformation of the input imaging data, containing all the information required for image reconstruction.
- Visibilities are complex numbers with amplitude and phase.
- Visibilities are also the fundamental input to imaging with radio interferometry, where they are matched by correlating signals from widely separated antennas.

How are they measured by RHESSI?

- Measured visibility amplitude and phase for subcollimator 3 as a function of heliographic position angle. (The statistical error in amplitude is shown as the light line at the bottom.)
- Starting from stacked events, count rates in each roll bin are fit with a sinusoid plus offset.
- The calibrated visibility is the amplitude of the sinusoidal fit, after normalization for grid transmission, modulation and detector efficiency.

APPLICATIONS

- By combining visibilities as a function of time and energy, 
  - Enhances statistical sensitivity by enabling data weighting
  - Provides a compact starting point for imaging algorithms
  - Useful for iterative processing
  - Enables use of highly developed image reconstruction packages developed for radio interferometry
  - Improves \chi^2 sensitivity in mapping algorithms.

- Can accurately determine source parameters (e.g., diameter, ellipticity, source separation) without algorithm-dependent mapping.
- Redundancies provide a sensitive tool for self calibration of grid parameters.

SUMMARY

- Stacking data using spacecraft roll angle and aspect phase makes long data sets equivalent to a single rotation.
- Stacking has significant advantages for imaging, and enables the calculation of visibilities.
- Visibilities are direct, calibrated measurements of specific Fourier components of the source spatial structure.
- They provide a powerful intermediate data product and an alternative starting point for image reconstruction.

SOURCE SIZE AND SHAPE EXAMPLES

Visibilities enable the FWHM diameter to be determined independently at each position angle.

For a circularly symmetric source, the amplitude as a function of spatial frequency depends on the source diameter.

In this case, a Gaussian fit yields an average diameter of 6.1 arcseconds.

The ellipticity of the source, only weakly suggested by the image, is well determined by the visibility analysis.

Polar plot of amplitudes for subcollimator 5.

Independent of source morphology, the amplitudes should be identical at opposite position angles.

The obvious offset is an indicator of a small (~1 arcsec) error in the current grid fit calibration.

Self-calibration examples

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Histogram of phase errors for opposite position angles for grids 3 and 5.

Independent of source morphology, the phases should have opposite signs at opposite position angles. This is true for grid 5 (right) but for grid 3 (left), the 12.5+1.5 degree offset corresponds to a 1/8 + 0.2 integer error in grid phase calibration (~0.24 arcsec).

Source size and shape example

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