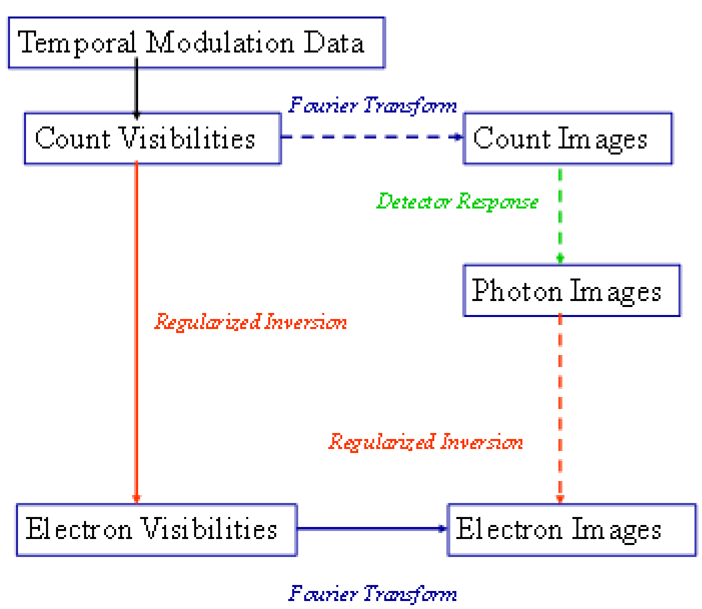
Regularized Electron Flux Visibility Spectra

Just like count visibilities are two-dimensional Fourier transforms of the count-based image in given count energy channel and time interval, electron flux visibilities are two-dimensional Fourier transforms of the electron flux spectrum in a given electron energy bin and time interval.

A basic goal of hard X-ray imaging spectroscopy is to determine the spatial and temporal variation of electron flux that is responsible for the hard X-ray emission. In principle, this can be done through the following "straightforward" approach: A series of count-based images are produced by Fourier transforming the corresponding count-based visibilities, obtained from RHESSI data. "Stacking" images at different energies allows the count spectrum within a given subregion of the source to be determined. Knowledge of the detector response matrix then allows determination of the corresponding photon spectrum in the subregion in question, and this can then be inverted, through a regularized spectral inversion process (see, e.g., http://adsabs.harvard.edu/abs/2003ApJ...595L.127P) that uses knowledge of the applicable bremsstrahlung cross-section, to obtain the corresponding responsible electron spectrum in that region. This process is indicated by the dashed lines in the figure below. However, since count-based images in different energy channels are based on completely independent sets of counts, the statistical noise from one count energy channel to the next is uncorrelated. This results in rather noisy count spectra, and this noise is often amplified by the ill-posed spectral inversion process, yielding unacceptably noisy (and even unphysical) electron spectra.



The solution to this conundrum lies in noting that the regularized spectral inversion process is inherently a linear operation. Since the Fourier transform is also a linear operator, the operations of spectral inversion and Fourier transform can be applied in either order. First, the count visibilities are subjected to a regularized spectral inversion (which incorporates both the bremsstrahlung cross-section and the detector response matrix in the kernel – see Appendix A of http://adsabs.harvard.edu/abs/2007ApJ...665..846P) to produce electron visibilities. These electron visibilities can then be Fourier-transformed to yield electron flux images (in practice this is done using one of a number of image-processing algorithms such as uv_smooth – http://adsabs.harvard.edu/abs/2009ApJ...703.2004M - Maximum Entropy - http://adsabs.harvard.edu/abs/2006ApJ...636.1159B - or clean). This order of processing is represented by the solid lines in the figure above.

Because the electron visibilities are constructed through a regularized spectral inversion process, they necessarily vary smoothly with energy, and therefore so also do the electron images that result from Fourier-transforming them. Thus, "stacking" of electron images obtained in this manner generates smooth electron spectra in specified subregions of the source, and so allows the variation of electron flux with position to be reliably determined. This can in turn be used to study energy loss and transport processes (see, e.g., http://adsabs.harvard.edu/abs/2012ApJ...751..129T)

Because RHESSI data produces images in the plane of the sky, the electron images obtained are necessarily weighted by the average line-of-sight column density over the subregion under investigation. For details, see Appendix A of http://adsabs.harvard.edu/abs/2007ApJ...665..846P .