STIX Co-location – Windisch
November 15th, 2022

# Electron visibilities and electron maps for STIX

**Anna Maria Massone and the MIDA group**

# From photon to electron visibilities

- Photon visibility definition:

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

- Bremsstrahlung equation:

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

- Electron visibility definition:

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

- 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;ε)*

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

# Electron maps

**Algorithm for electron image reconstruction**:

1. for each (u,v) pair solve

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

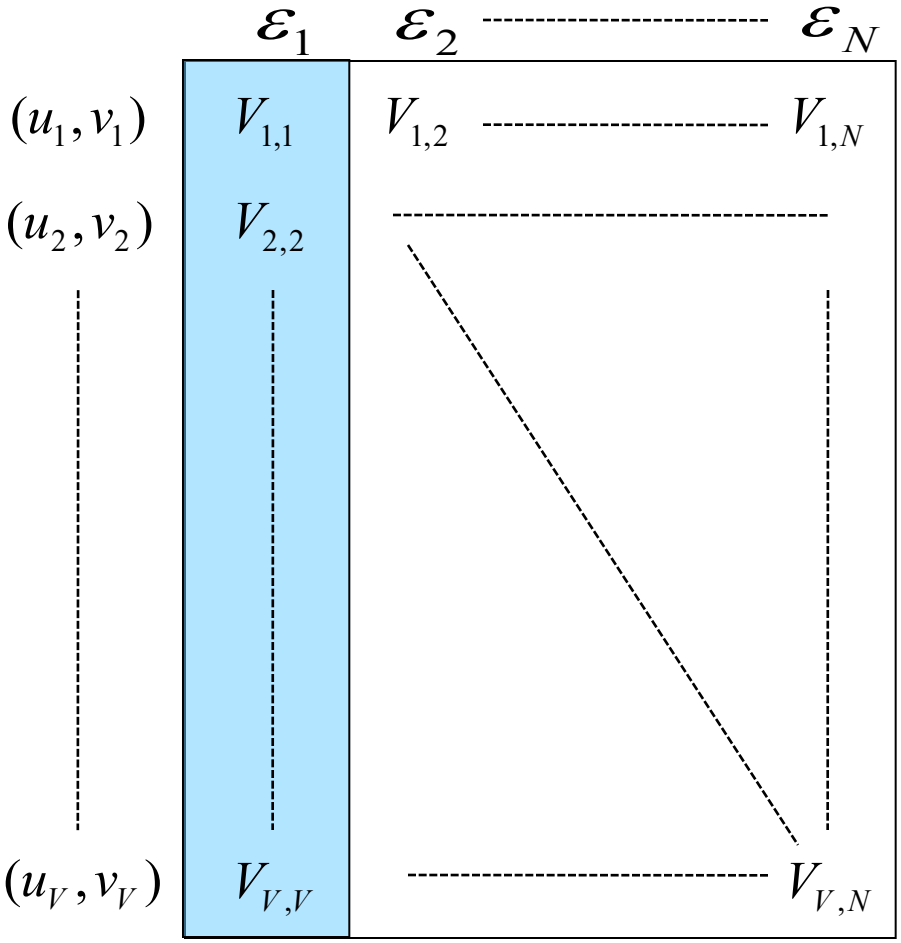
by means of Tikhonov regularization algorithm (which smoothes along the energy direction)

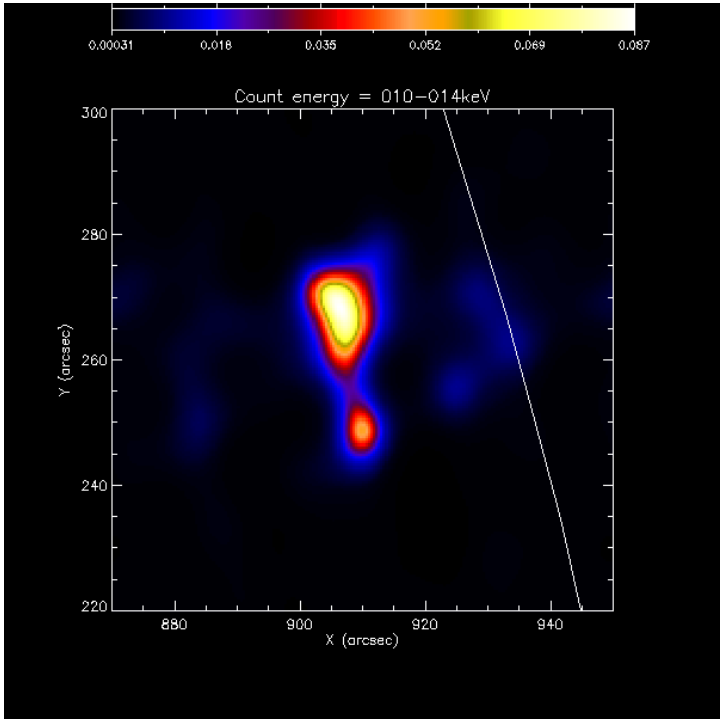
2. for each E solve

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

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

# Visibility inversion algorithm: implementation



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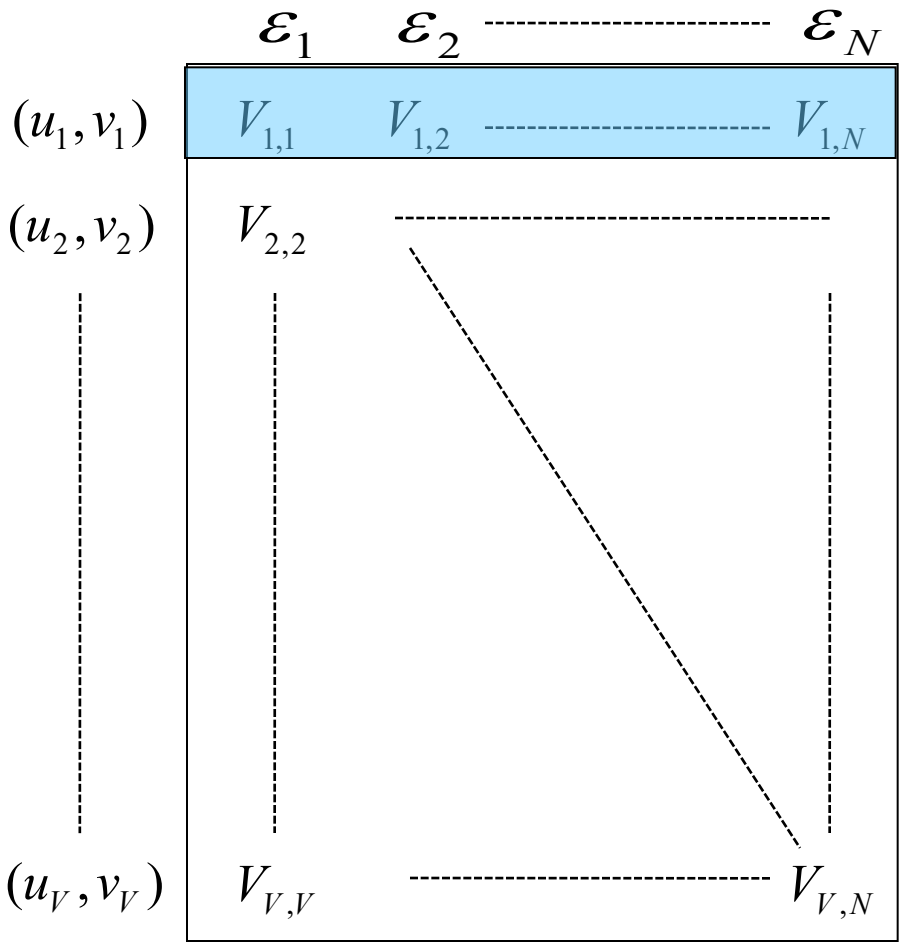


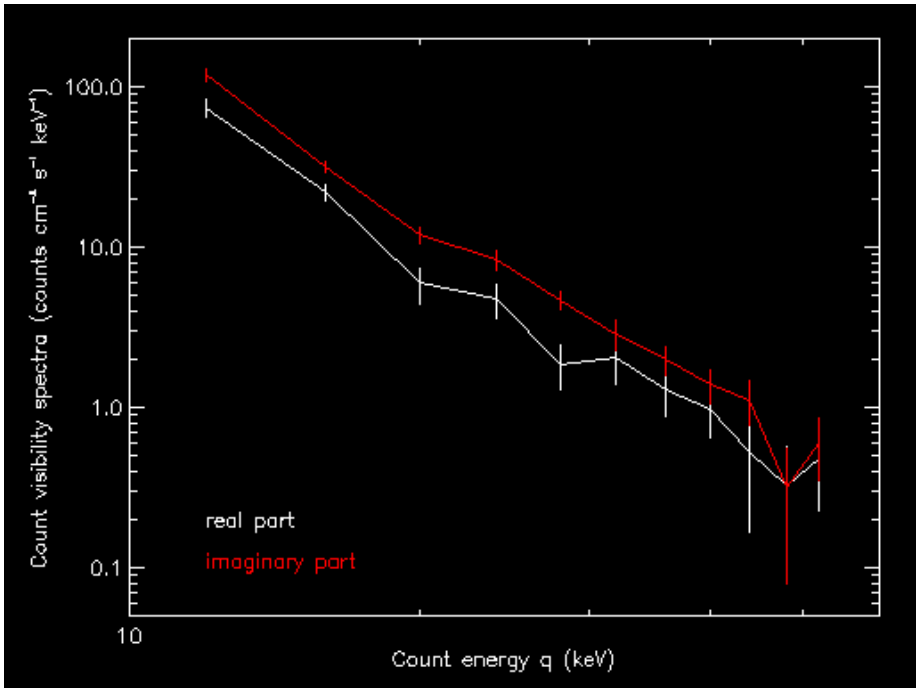


$$V(u_1, v_1; \varepsilon)$$

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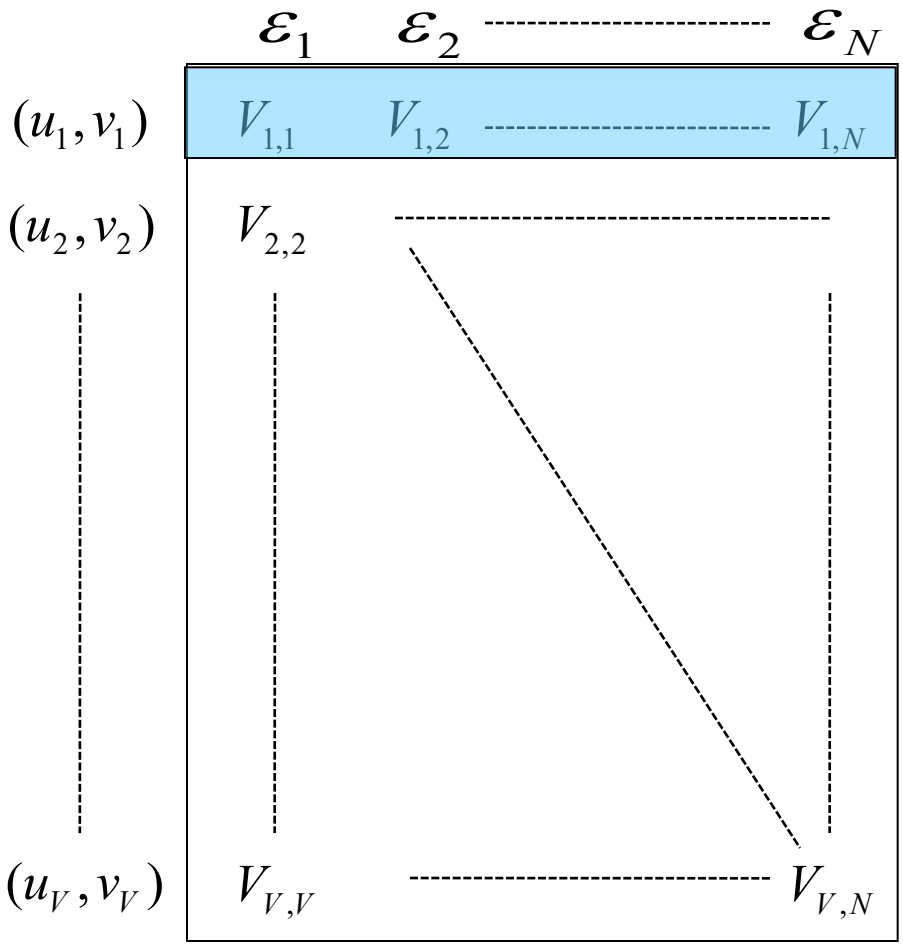


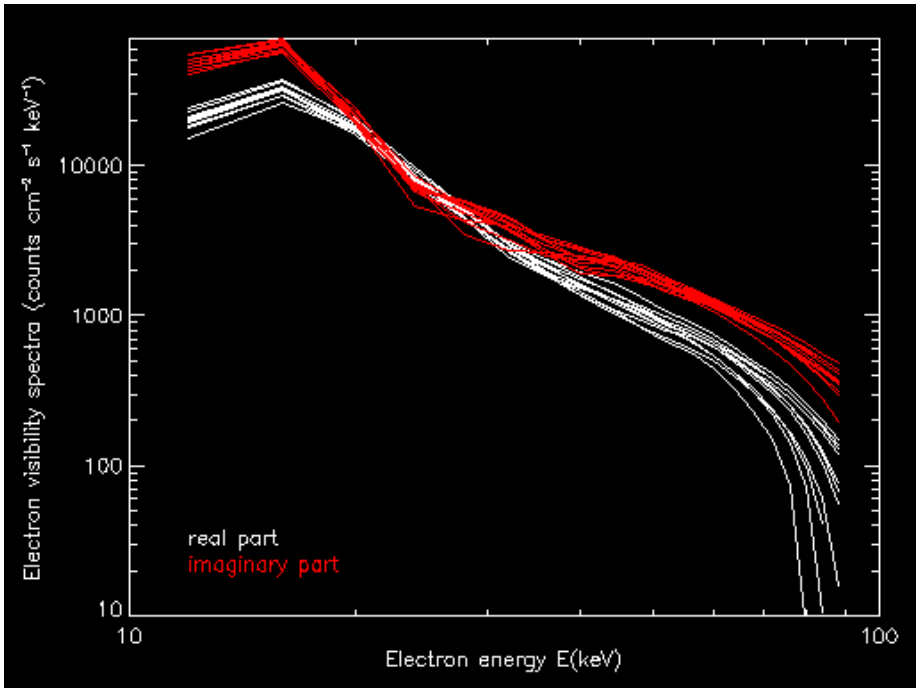


$$W(u_1, v_1; E)$$

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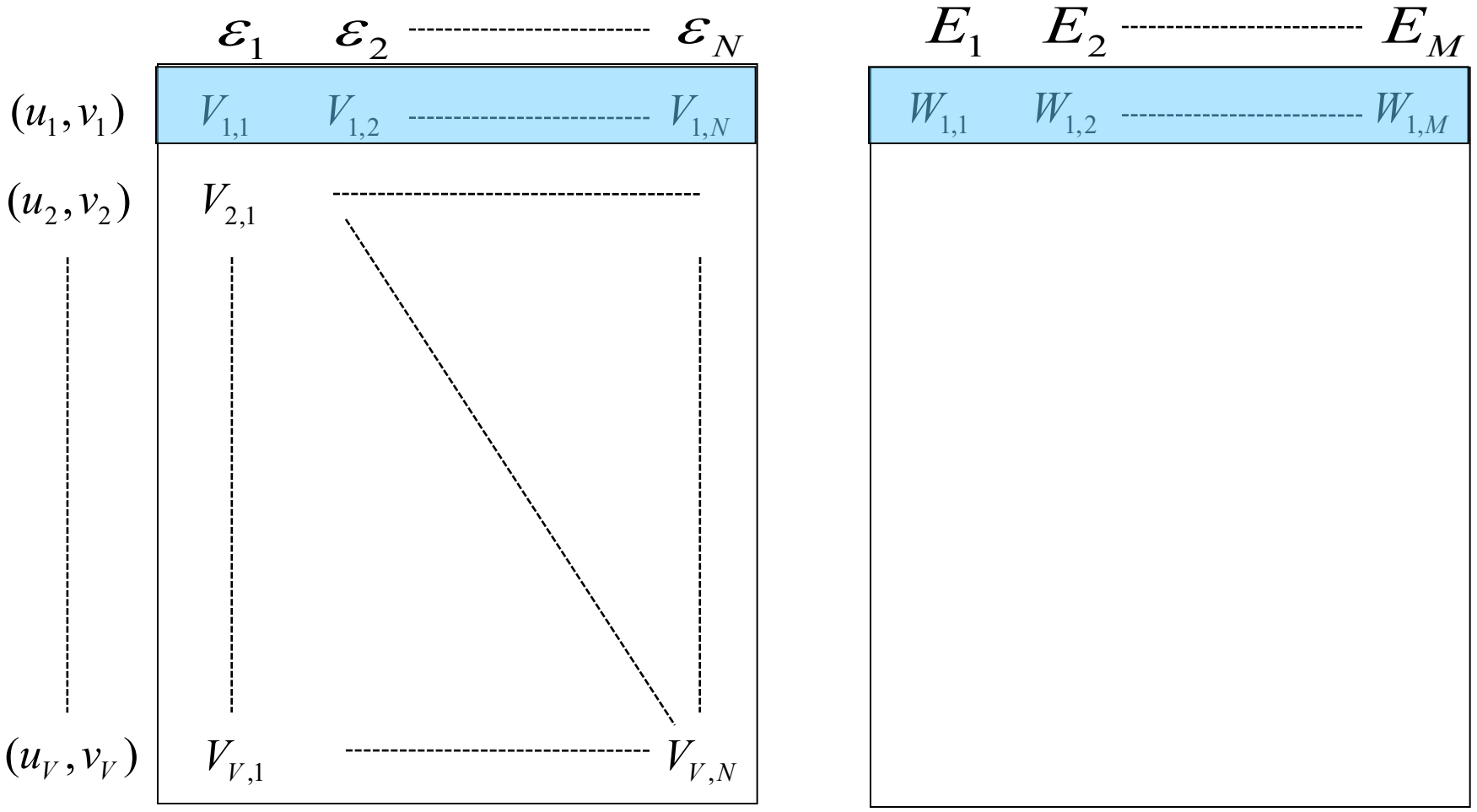
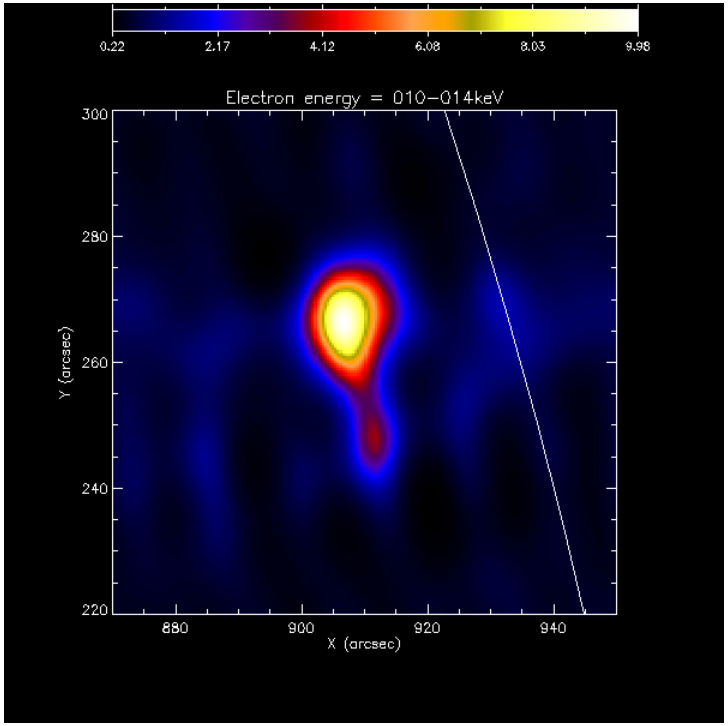
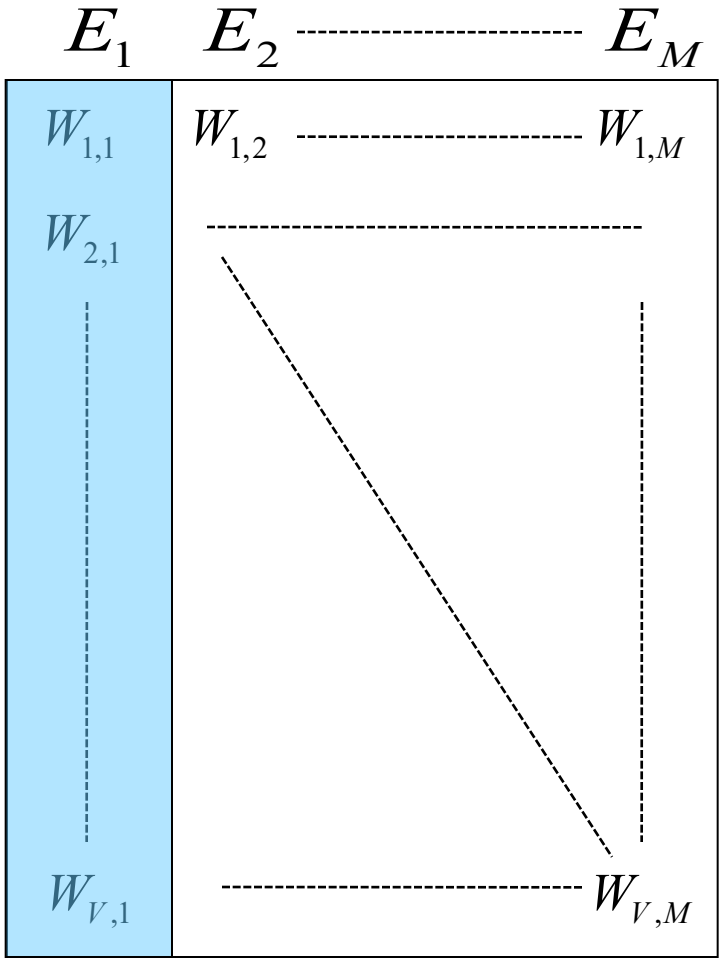


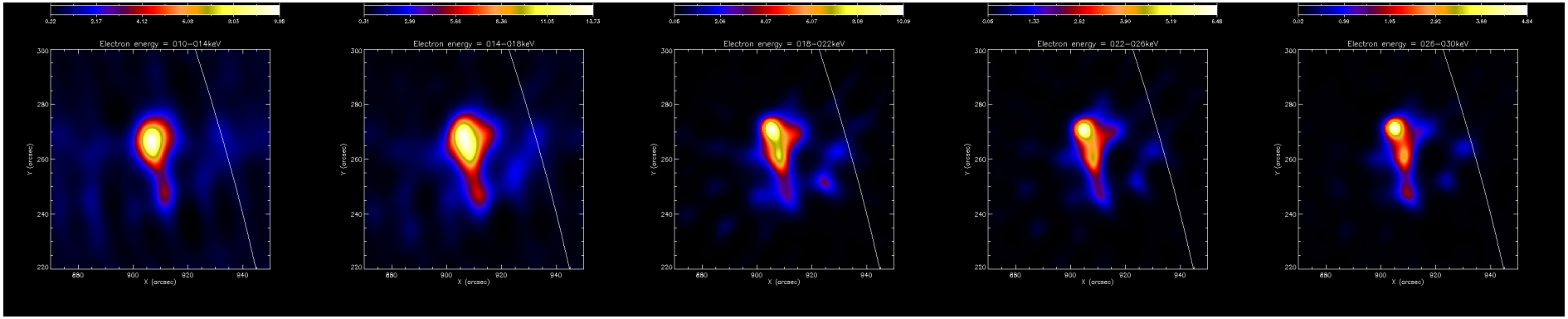
# From electron visibilities to electron maps



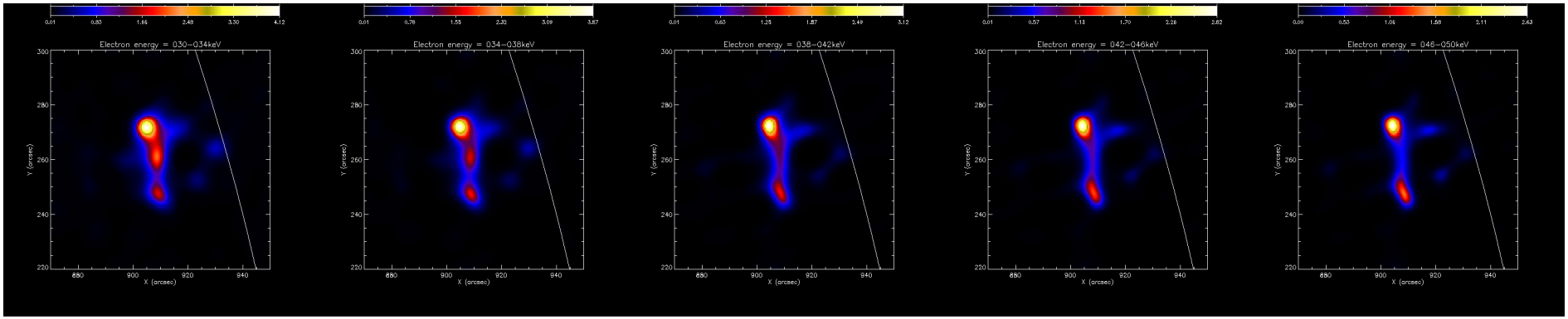



# Visibility-based electron maps

Imaging from visibilities: MEM




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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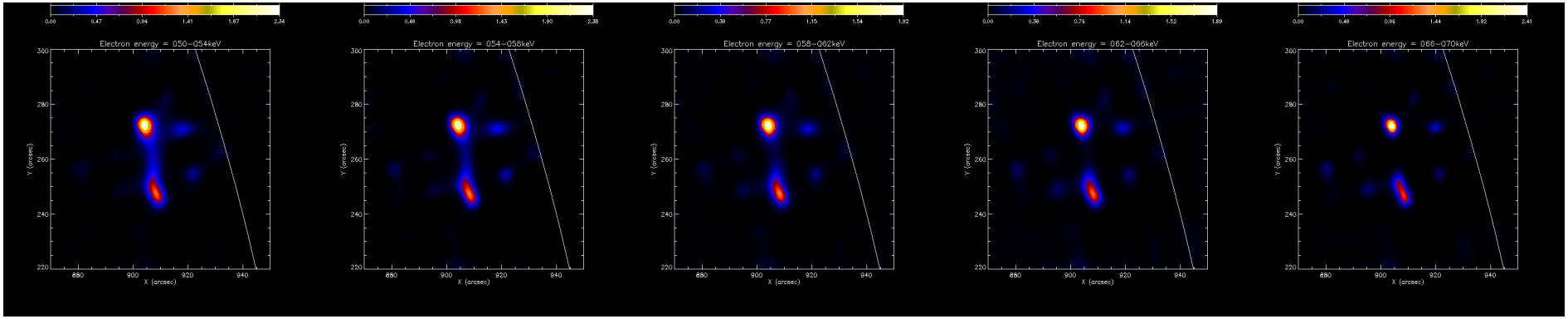
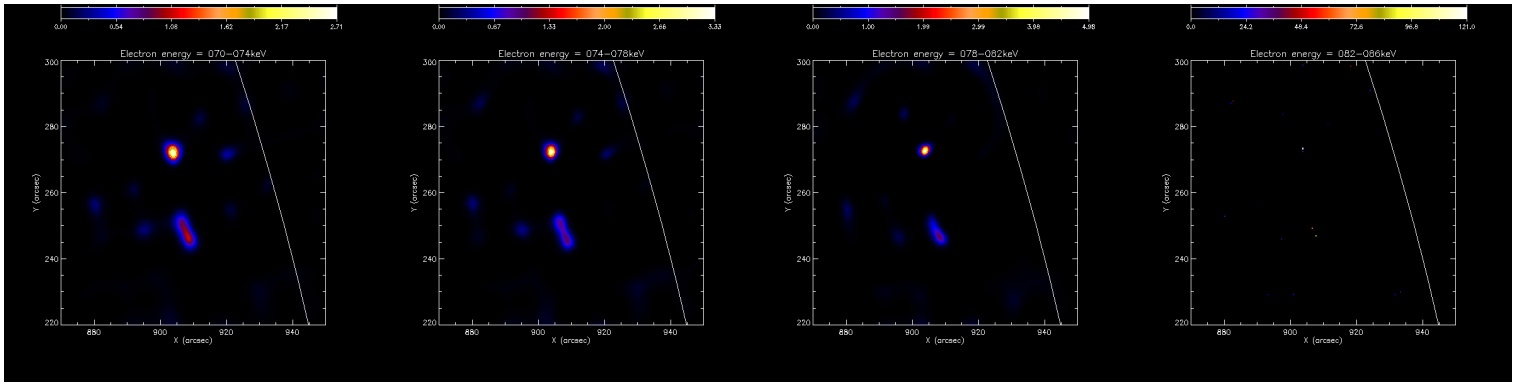
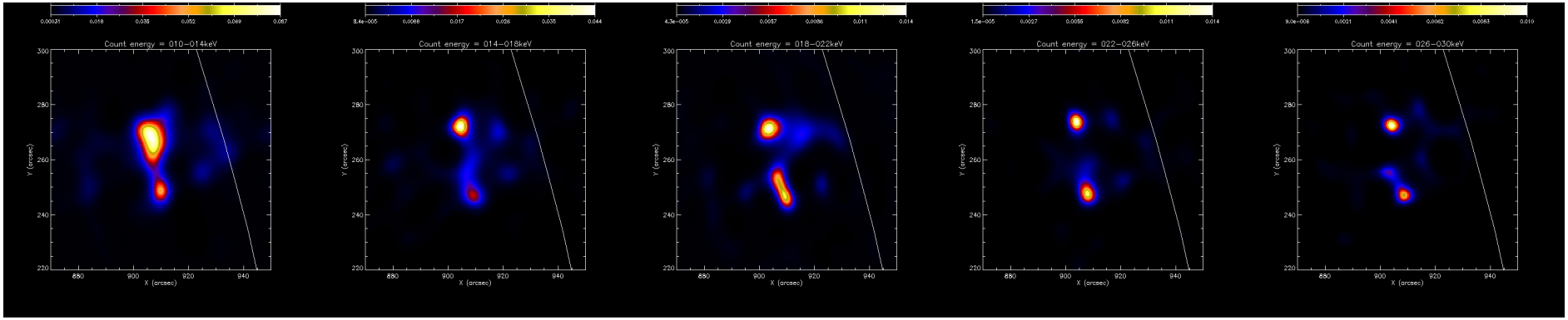



50-54 keV | 54-58 keV | 58-62 keV | 62-66 keV | 66-70 keV




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

# Photon maps vs electron maps

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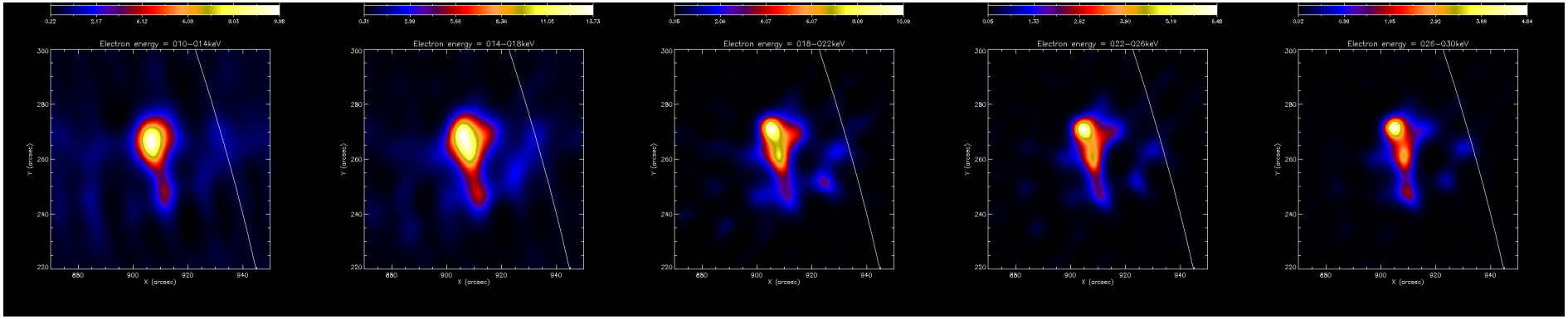

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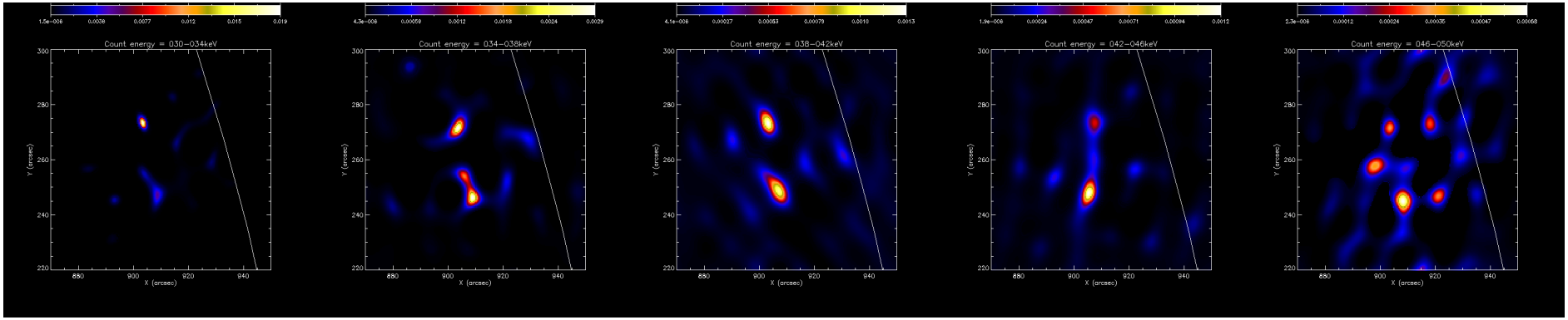


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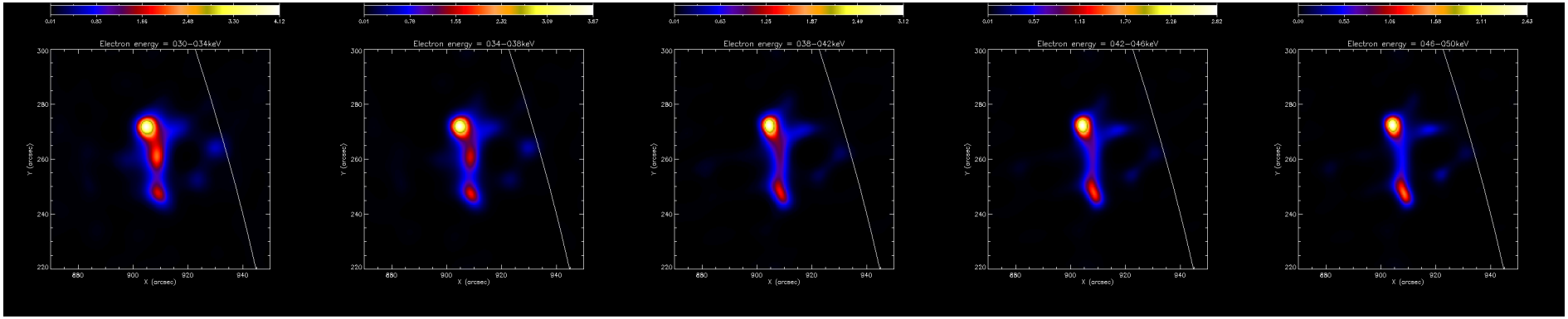

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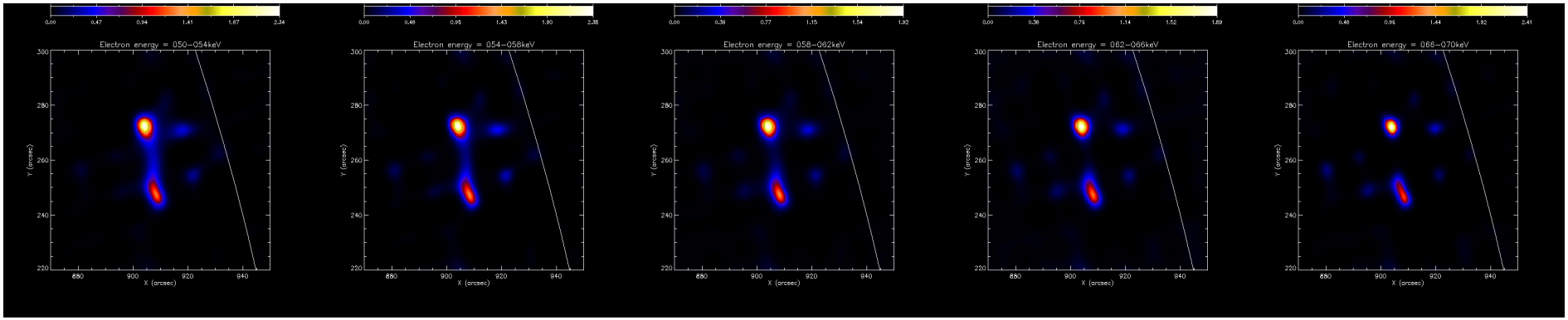

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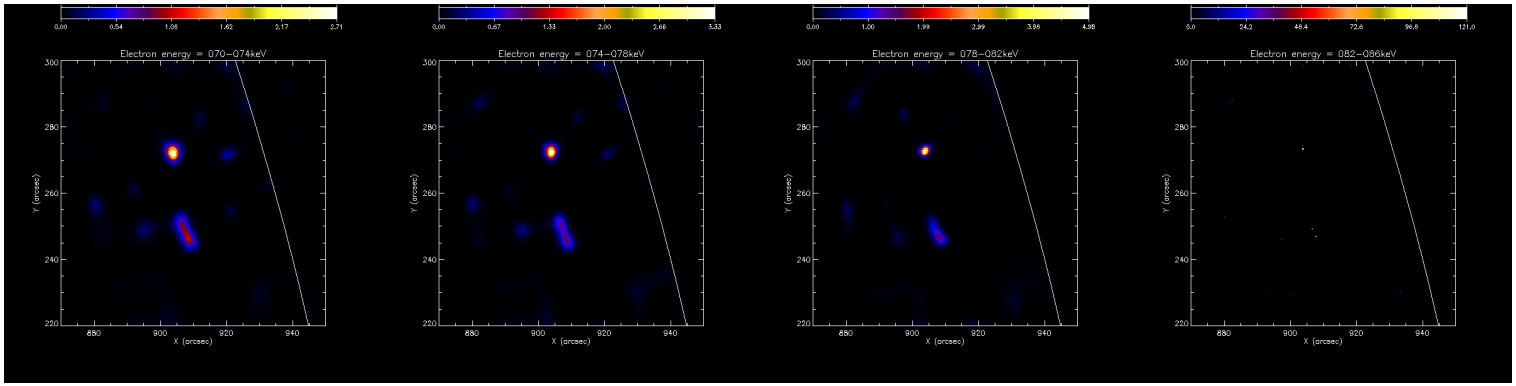

# APPLICABILITY CONDITIONS – FROM RHESSI TO STIX

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