On the reconstruction of the electron density structures in the corona from 1.5 to 4 Rsun

M.Kramar\textsuperscript{1}, S.I.Jones\textsuperscript{2}, J.Davila\textsuperscript{3}, B.Inhester\textsuperscript{4}, M.Mierla\textsuperscript{5}

\textsuperscript{1} The Catholic University of America, NASA-Goddard Space Flight Center
\textsuperscript{2} University of Maryland, NASA-Goddard Space Flight Center
\textsuperscript{3} NASA-Goddard Space Flight Center
\textsuperscript{4} Max-Planck Institute for Solar System Research, Germany
\textsuperscript{5} Astronomical Institute of the Romanian Academy, Romania
Tomography for the Solar Corona

• Problem is badly conditioned, e.g. number of unknown variables exceeds the number of equations
• Noise in the data

\[ \text{Regularization should be applied} \]

• Stationarity of the corona during the observations must be assumed. Coronal observations are restricted to only one-three view direction in ecliptic plane.
Scalar Field Tomography: Regularization

- Problem is badly conditioned, e.g. number of unknown variables exceeds the number of equations
- Random noise in the data

In result, there is possible no unique reconstruction. Problem is ill-conditioned.

\[
F = \sum_{i=1}^{\text{Number of Rays}} \left( I_i^{\text{sim}} - I_i^{\text{obs}} \right)^2 + \mu \cdot F_{\text{reg}} = \\
= \left| A \cdot X - Y \right|^2 + \mu \cdot \left| L \cdot X \right|^2
\]
Tomographic Reconstruction for the Solar Corona

Input:
- COR1B observations: pB images, 341x341 pixels
- Two weeks, ~ twice per day: 3 – 16 July 2007
- Monthly minimum background subtracted
- Starting point for the iterations is flat field (constant density)

Output:
- 3D Electron Density Distribution: 128x128x128 pixels
Reconstruction of the Electron Density

Isosurface: $N_e = 3.6 \times 10^{10}$ m$^{-3}$

Inner spherical boundary is at 1.5 $R_{\text{sun}}$
Reconstruction of the Electron Density

Isosurface: $N_e = 3.6 \times 10^{10}$ m$^{-3}$

Inner spherical boundary is at 1.5 $R_{\text{sun}}$
Reconstruction of the Electron Density

Isosurface: $N_e = 3.6 \times 10^{10}$ m$^{-3}$

Inner spherical boundary is at 1.5 $R_{\text{Sun}}$
Isosurface: $N_e = 3.6 \times 10^{10} \text{ m}^{-3}$

Inner spherical boundary is at $1.5 \ R_{\text{sun}}$
Isosurface: $N_e = 3.6 \times 10^{10} \text{ m}^{-3}$

Inner spherical boundary is at 1.5 $R_{\text{sun}}$
Reconstruction of the Electron Density

Isosurface: $N_e = 3.6 \times 10^{10}$ m$^{-3}$

Inner spherical boundary is at 1.5 $R_{\text{sun}}$
Reconstruction of the Electron Density

Isosurface: $N_e = 3.6 \times 10^{10} \text{ m}^{-3}$

Inner spherical boundary is at 1.5 $R_{\text{sun}}$
Reconstruction of the Electron Density

Isosurface: $N_e = 3.6 \times 10^{10} \, \text{m}^{-3}$

Inner spherical boundary is at $1.5 \, R_{\text{sun}}$
Observation: pB image.

Reconstruction: Vertical cross-section.

White contour lines are boundary between open and closed magnetic field lines in potential field reconstruction with SS=2.5\(R_{\text{Sun}}\).
Spherical cross-section at $2 R_{\text{sun}}$

White contour lines are boundary between open and closed magnetic field lines in potential field reconstruction with $SS = 2.5 R_{\text{sun}}$.

Black contour line is the magnetic neutral line.

MHD simulation (http://iMHD.net/stereo)
Reconstruction

$\phi_{\text{LOS}} = 0^\circ$
$\theta_{\text{LOS}} = 90^\circ$
3D Electron Density: Streamer

Total Brightness

3D Position of the streamer has been found by triangulation method
3D Electron Density: Streamer

Red lines on pictures below are the streamer’s positions found by triangulation method.

Cross-section by plane perpendicular to $z$-axis (carrington system)
Acknowledgments

William Thompson

James McAteer

Gordon Petrie

Potential Field Approximation code was adopted from J.Luhmann’s code.

Richard Frazin

Pete Riley, Jon Linker