

Solar Coronal Tomography

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2008 OpTeC Conference, Bozeman, MT



Abstract

A simple, yet powerful, algorithm for computed tomography of the solar corona is demonstrated using synthetic EUV data. A minimum of three perspectives are required. These may be obtained from *STEREO*/EUVI plus an instrument near Earth, e.g. *TRACE* or *SOHO*/EIT.

Coronal Tomography (EUV)



1. Why is the Solar Corona important?
2. Background—*STEREO* mission
3. Science Goals
4. SMART Algorithm
5. **Demonstration** (synthetic EUV data)
6. Summary & conclusions

Why is the Corona interesting?

Solar Physics

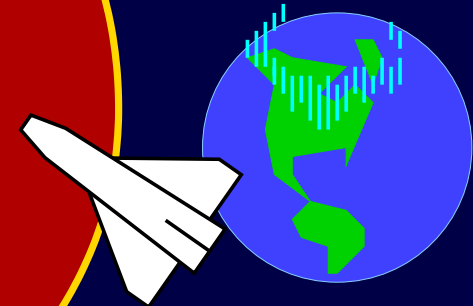
- Coronal heating
- Solar flares
- Coronal mass ejections

Geoeffect

- Aurorae
- Communications
- Power systems

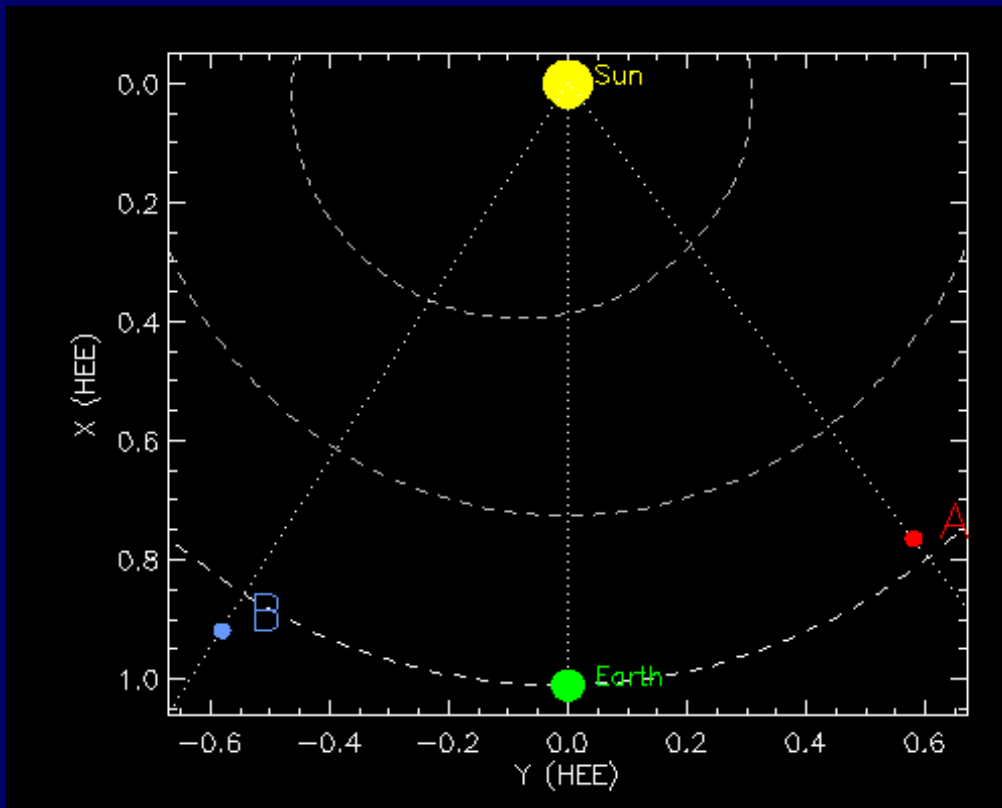
Aerospace systems

- Radiation environment
- Human safety
- Electronics
- Satellite drag



NASA's *STEREO* Mission

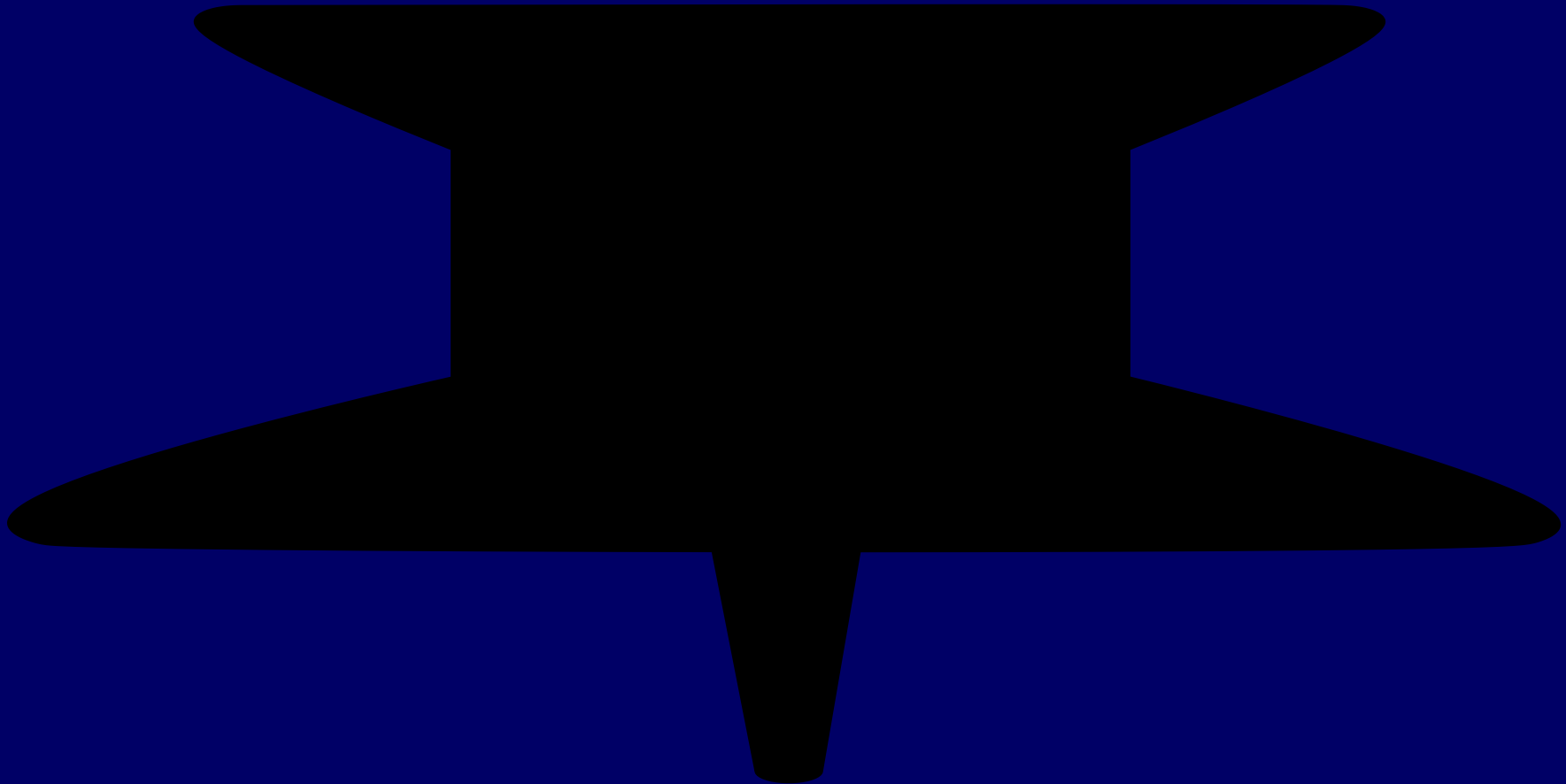
(SECCHI remote sensing pkg)



- Twin spacecraft in solar orbit
- A = Ahead, B = Behind
- EUVI = Extreme UV Imager (low corona)
- Coronagraphs observe outer corona
- Heliospheric Imager
- Like human stereoscopic vision (?)

STEREO Aug 27 ($-32^\circ, +37^\circ$)

Example EUVI Data (171 Å)



A primary science question of *STEREO*/SECCHI is:

What is the 3-dimensional structure of active regions, coronal loops, helmet streamers, etc?¹

Approach:

- Adapt Smooth Multiplicative Algebraic Reconstruction Technique (*SMART*) algorithm developed for *MOSES*.
- 3 views: *STEREO*/EUVI + *TRACE* (EUV telescope in LEO, launched April 1998).

¹Howard et al. 2007, *Space Science Reviews*

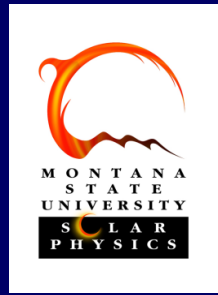
Inspiration from *MOSES*

What does this sounding rocket have to do with *STEREO*?

- *Multi-Order Solar EUV Spectrograph (MOSES)*
- NASA LCAS launch, 2006 Feb 8
- Simultaneous imaging and spectroscopy
- Tomographic inversion → spectrum
- Synergy with *STEREO* few-angle tomography



Problem Statement



Observe volume EM $I(x, y, z)$ at angles θ_i by projection:

$$f_i(x, z) = \int_D \mathcal{R}_z(\theta_i) I dy + \text{noise}$$

Given images f_i and initial guess $G(x, y, z)$, iteratively modify G to approximate I .



SMART Algorithm



1.



SMART Algorithm



1. Smooth G .

SMART Algorithm

1. Smooth G .

2. Project: $f'_i = \int_D \mathcal{R}_z(\theta_i) G dy \quad \forall i$

- Evaluate goodness of fit, $\chi_{R,i}^2$
- Adjust γ_i based on $\chi_{R,i}^2$ and $\Delta\chi_{R,i}^2$

SMART Algorithm

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3. Correct: $G \leftarrow G \prod_i C_i^{\gamma_i}$, where

$$C_i(x, y, z) = \mathcal{R}_z(-\theta_i) \frac{f_i(x, z)}{f'_i(x, z)}.$$

SMART Algorithm

1. Smooth G .

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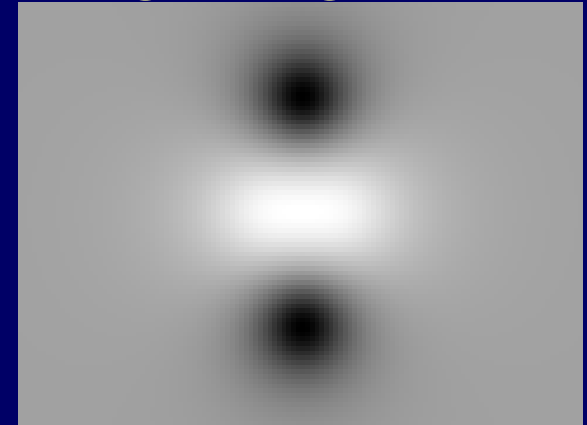
$$C_i(x, y, z) = \mathcal{R}_z(-\theta_i) \frac{f_i(x, z)}{f'_i(x, z)}.$$

Iterate, adjusting γ_i to drive $\chi_{R,i}^2 \rightarrow 1$.

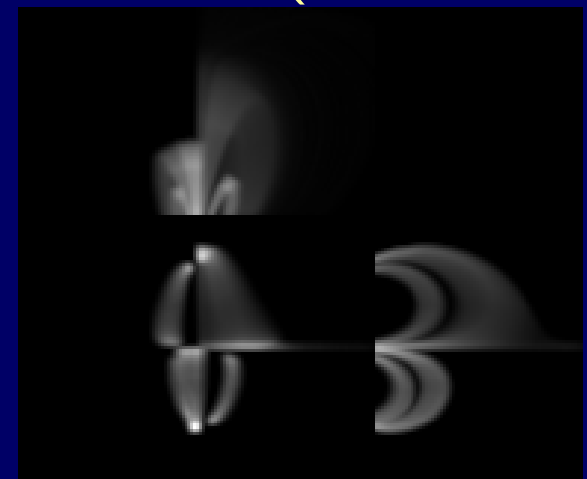
Synthetic Data

- Quadrupole potential field
- Coronal null: interesting geometry
- EM along arbitrary field lines
- Random latitude, longitude & clocking
- 3 viewpoints: $-40^\circ, 0^\circ, +40^\circ$
- Imaged with 3000 counts in the brightest pixel
- Note square root scaling

Magnetogram:



Corona (isometric):



Example 1 (E-W pan)

True (left) *vs.* SMART (right). Square root scaled.

Example 1 (N-S pan)

True (left) *vs.* SMART (right). Square root scaled.

Example 2 (E-W pan)

True (left) *vs.* SMART (right). Square root scaled.

Example 2 (N-S pan)

True (left) *vs.* SMART (right). Square root scaled.

Summary & Conclusions



- Full 3D reconstruction of coronal EM
- 3 viewpoints required
- No assumptions (loops, magnetic field, etc.)
- Simple and computationally efficient
 - Examples converged in 15 iterations
 - 3 minutes on my laptop (169^3 voxels)
- Loops parallel to ecliptic—not so good
- Apply to EUVI data hopefully this fall!

Acknowledgment: This work has been funded through the Solar and Heliospheric LCAS Program.