3-D RECONSTRUCTION AND VISUALIZATION

3-D R&V Approaches at NRL for Coronagraphs

Dennis G. Socker, John W. Cook,
Russell A. Howard, Paulett C. Liewer,
Eric DeJong, Patrick C. Crane,
Jeffrey S. Newmark, Dennis Wang

Objectives

- Develop techniques for the 3-D reconstruction and visualization of the electron density structure of the coronal
- Initial focus on polar plumes, equatorial streamers, and coronal mass ejections (CMEs)

Data sources

- Present
  - LASCO: C2, C3 time lapse
  - Synthetic: especially CMEs
- Eventual
  - STEREO/SECCHI: COR1, COR2, HI
    - Two vantage point
    - Time lapse

Elements of the Investigation

- Reconstruction Algorithms
- Information in total brightness (B) images
- Information in polarized (pB) images
- Geometry of the reconstruction problem
- Visualization
- Computational Methods

Reconstruction Algorithms

- Standard Tomographic Methods
  - Inappropriate because the coronal reconstruction is underdetermined when only a few projections are available.
- Maximum Entropy Methods
  - Fit a model to the data set
  - Use entropy as the goodness of fit metric

Reconstruction Algorithms

- Maximum Entropy Methods
  - Line projections through model f

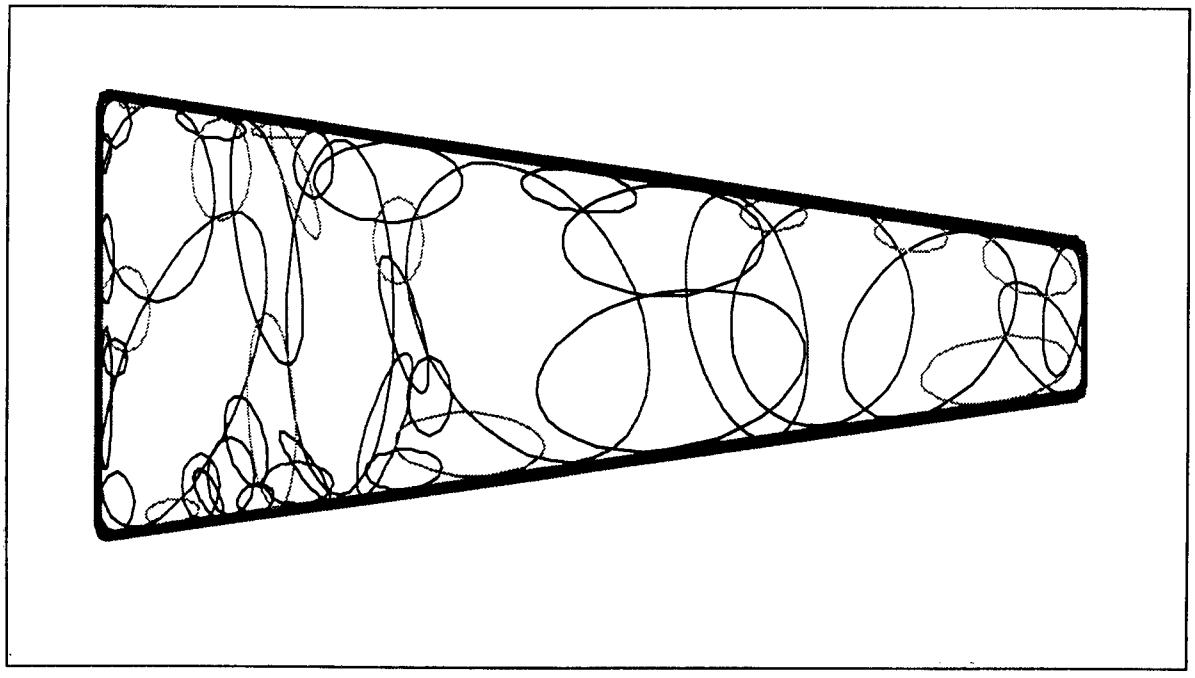
$$g(p,\hat{u}) = \int_{-\infty}^{\infty} f(p + s\hat{u})ds$$

  - Minimize (observed - predicted)

$$\chi^2 = \sum_i \frac{|g_i - \hat{g}_i|^2}{\sigma_i^2}$$

Reconstruction Algorithms

- PIXON
  - Models coronal structures by "filling" them with sets of spatially extended, overlapping and transparent elements called "pixons"
  - Iterative
  - Maximum Entropy at pixon level
  - Statistical pixon acceptance criteria



Information in (B) & (pB) Images

- Fraction of incident flux scattered

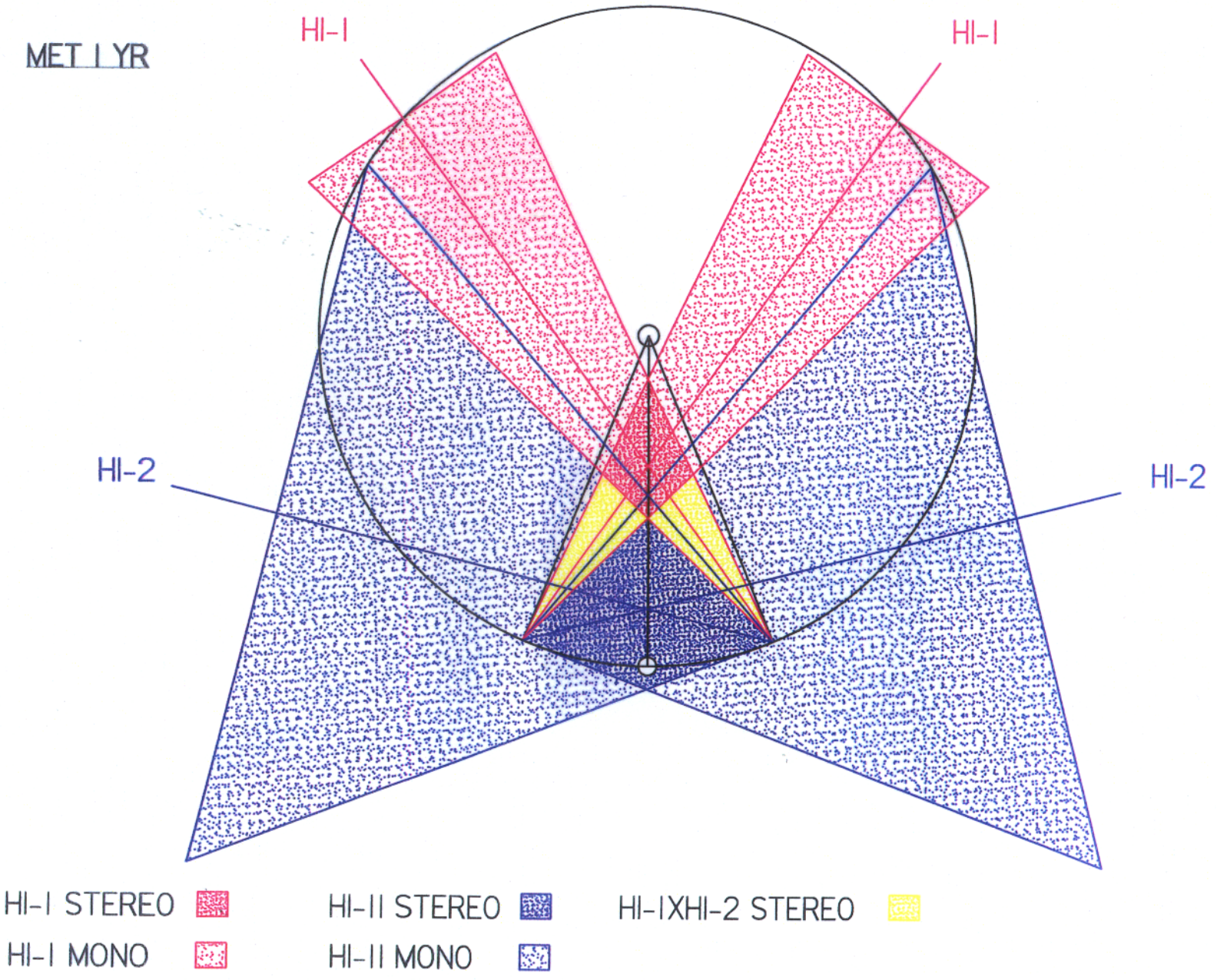
$$\frac{d\sigma}{d\Omega} = r_0^{\,2}\,\frac{1+\cos^2\theta}{2}$$

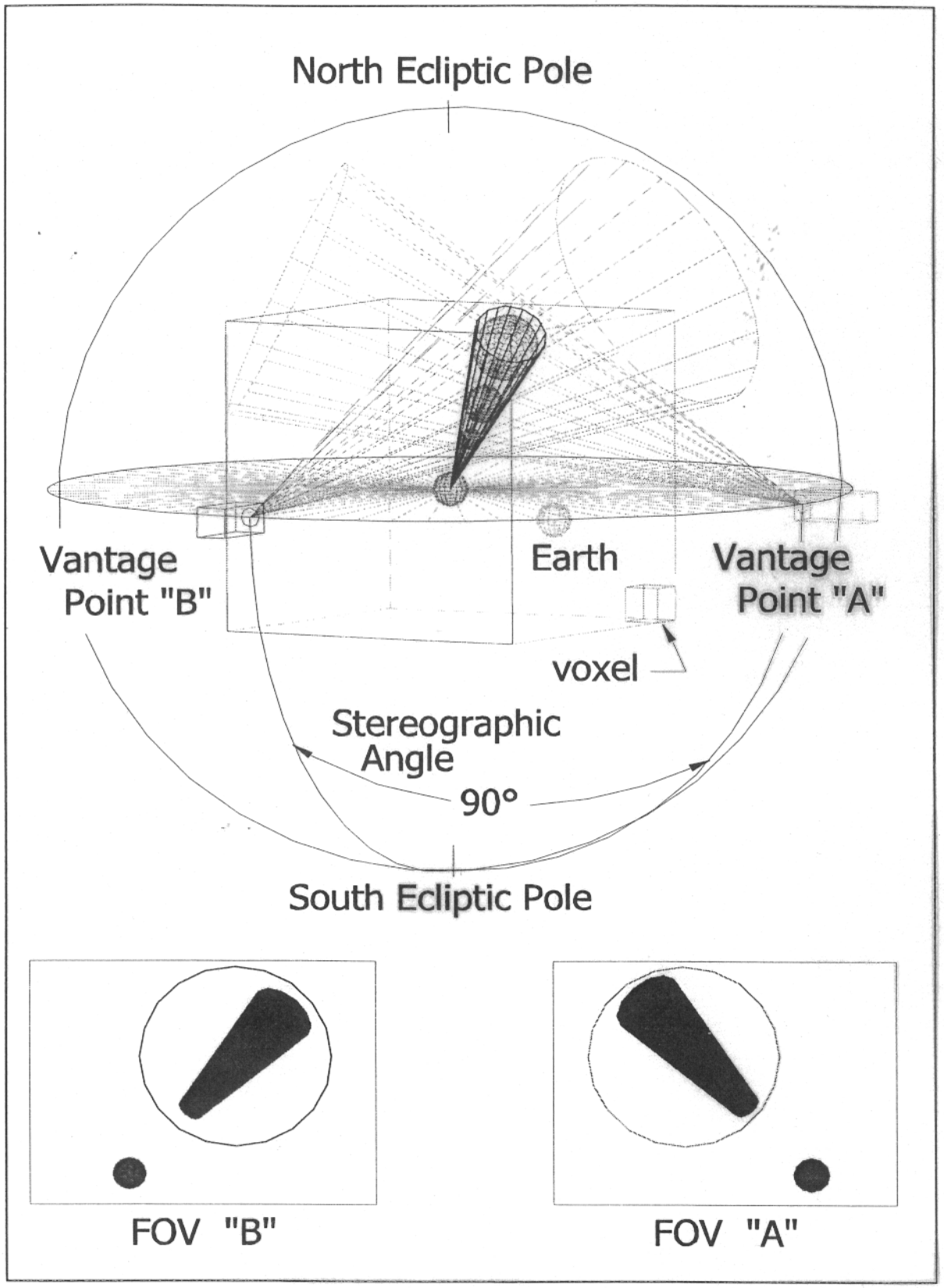
- Fractional polarization

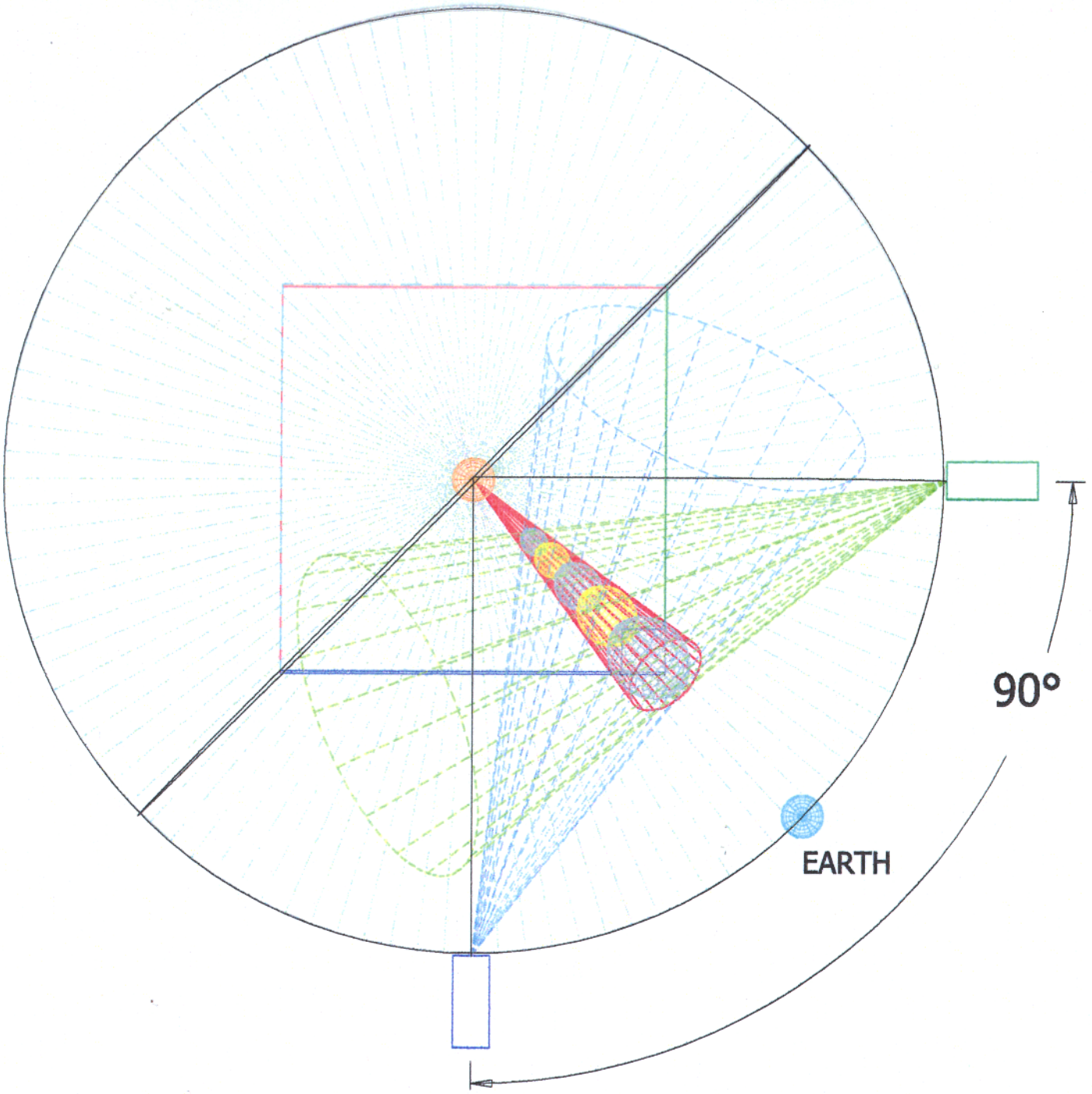
$$\Pi = \frac{1-\cos^2\theta}{1+\cos^2\theta}$$

Geometry

- Large scale coronal features plus optically thin plasma result in a problematic geometry
  - Plane-parallel type treatment possible only in ecliptic plane


MET 1 YR
HI-1
HI-1
HI-2
HI-2
HI-1 STEREO
HI-1 MONO
HI-11 STEREO
HI-11 MONO
HI-1XHI-2 STEREO


North Ecliptic Pole
Vantage
Point "B"
Earth
Vantage
Point "A"
voxel
Stereographic
Angle
90°
South Ecliptic Pole
FOV "B"
FOV "A"

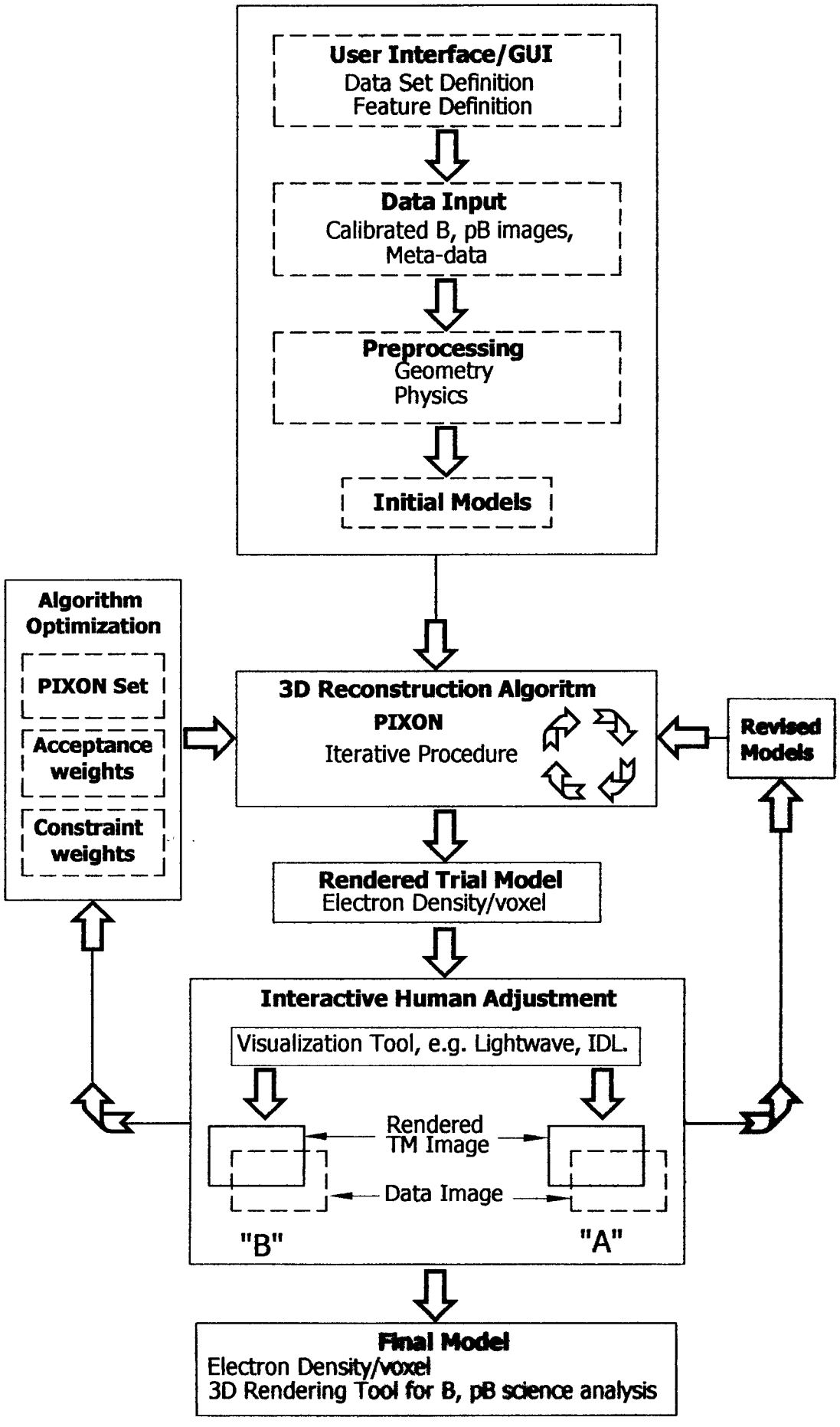

90°
EARTH

Visualization

- Problem: How to render optically thin plasma model in a useful manner ?
  - 3-D contour map
  - optically thick iso-density surfaces
  - cross-section 2-D contour maps
  - wire frame (CMEs)

Computational Methods

- What aspects can be parallelized ?
- How automated can the algorithm be ?
- What is the compromise between speed and accuracy ?
- To what degree can homolographic constraints be applied to time lapse image pairs ?


User Interface/GUI
Data Set Definition
Feature Definition
Data Input
Calibrated B, pB images,
Meta-data
Preprocessing
Geometry
Physics
Initial Models
Algorithm Optimization
PIXON Set
Acceptance weights
Constraint weights
3D Reconstruction Algoritm
PIXON
Iterative Procedure
Revised Models
Rendered Trial Model
Electron Density/voxel
Interactive Human Adjustment
Visualization Tool, e.g. Lightwave, IDL.
Rendered TM Image
Data Image
"B"
"A"
Final Model
Electron Density/voxel
3D Rendering Tool for B, pB science analysis