3D Sun Loop Trace: A Tool for Stereoscopy of Coronal Loops for STEREO

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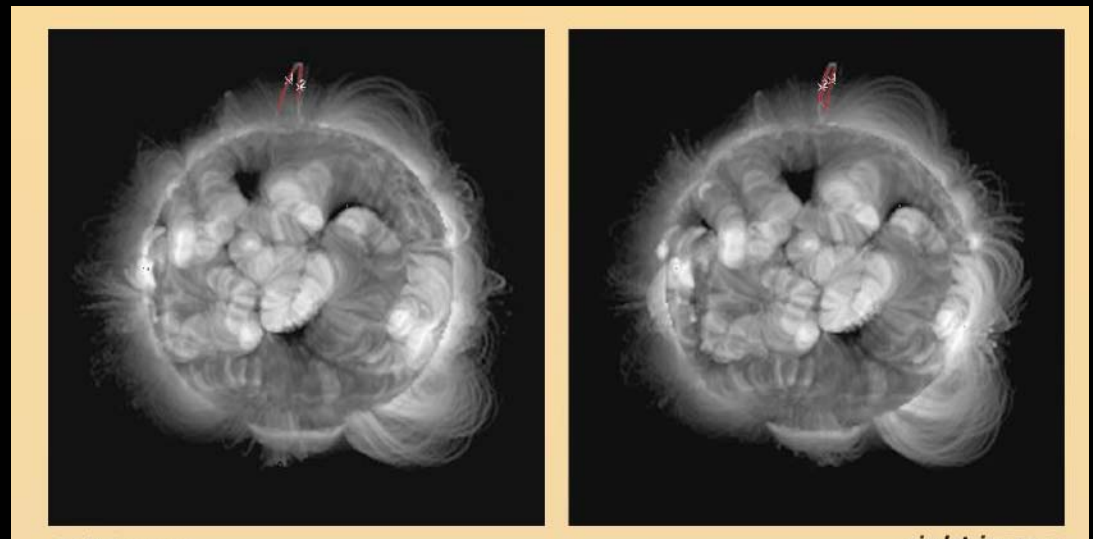Jeff Hall
Paulett Liewer
Parth Sheth
Eric DeJong
Jet Propulsion Laboratory

STEREO/SOLAR B Workshop, Oahu, Novermber 2005

3D Sun Loop Tracer - 3DSLT

Tool for reconstruction of corona loops from STEREO image pairs using triangulation
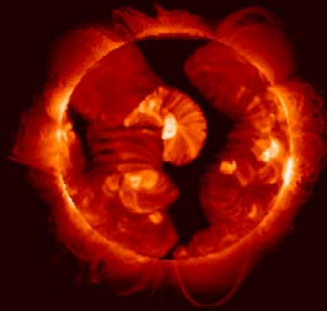
- Step 1 - User selects same loop in both images using cursor
- Step 2 - Program traces loop segments separately in each image and performs 3D reconstruction using triangulation
- Step 3 - Reconstructed loop plotted in 3D on solar sphere
  - User can rotate loop + sphere to verify loop reconstruction
  - Can also import field lines from potential field models, etc., for comparison
  - 3D coordinates of loop in heliographic coordinates also written to ascii file
- **Goal: Constrain extrapolated magnetic field models using reconstructed loops to determine pre-event energy stored in corona**
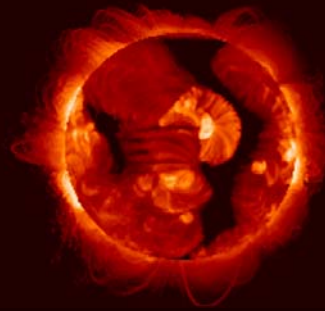
Synthetic Corona Data Set

Used synthetic corona data from *Schrijver et al (Ap J 2004)*

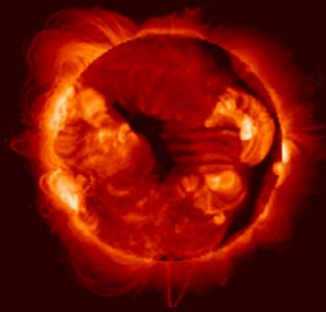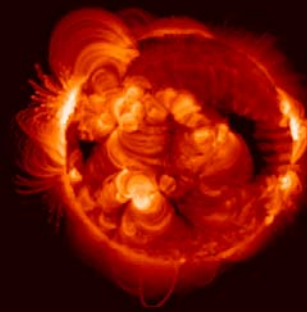*360 views of the synthetic corona - 1º spacing*
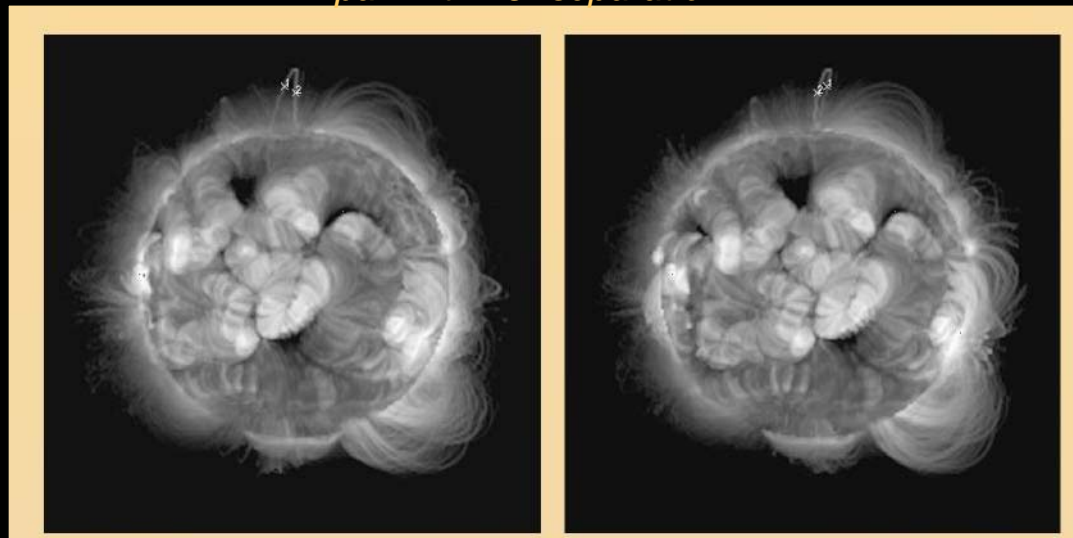
0º 15º

45º 90º

Used different "pairs" to study reconstruction for different stereo separation angles

Step 1: Select the loop in both images

User selects 'seed' points on the same loop in each image of the stereo pair using a cursor.

pair with 15º separation

Seed points can be anywhere on same loop segment

Here we show 2 selected seed points - "up" and "down" segments of the loop selected separately
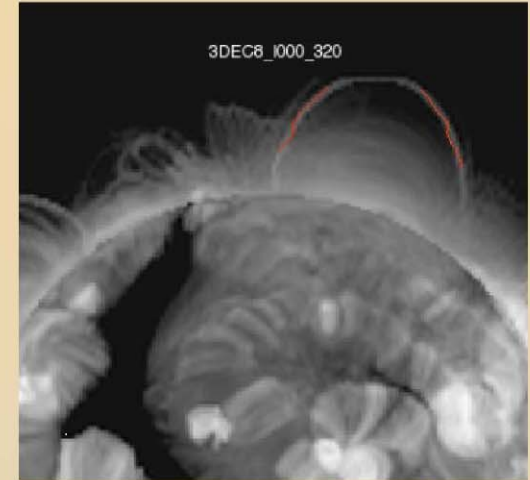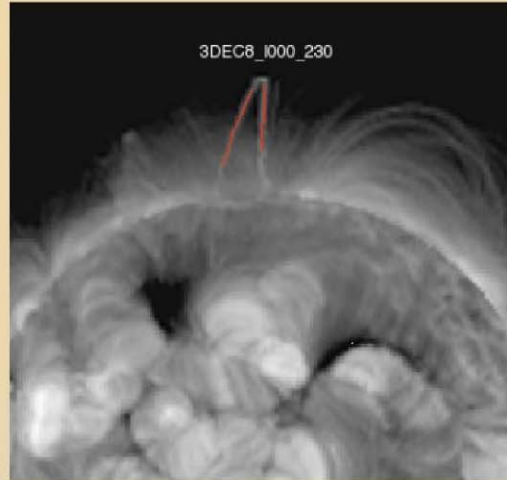
Step 2: Trace and Solve

Run the SUNLOOP algorithm to trace loop segments in each image and run XYZSUN to solve for 3D solar coordinates of points along the loop.

Loop coordinates are also written to an ascii file.
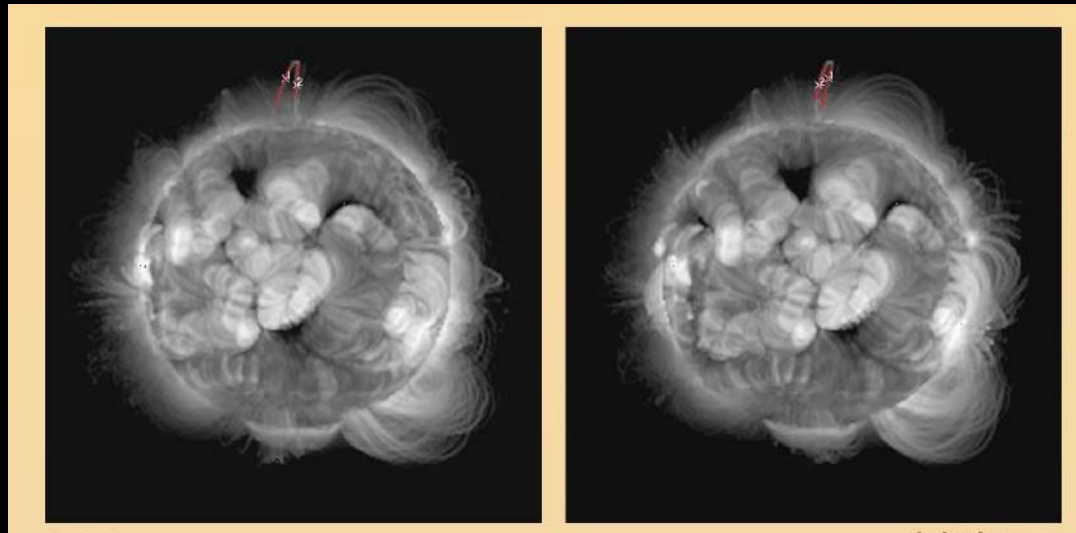
Red segments show reconstructed loop displayed on each image of the original stereo pair

rotated -45 degrees

rotated +90 degrees

Display results from different viewpoints by rotating Sun in interactive viewer window (see demo). Red reconstructed loop segments are now compared to views not used in the reconstruction.

For -45° and 90 °, reconstructed loop segments lie on the actual loop, verifying the reconstruction.

# Sample Use: Compare Reconstructed Loops with Models

- Reconstructed loop plotted in 3D on solar sphere
- Can also import field lines from magnetic field models to constrain models

  – Nonlinear force-free fields (NLFFFs) can be computed from vector magnetograms (e.g. Solar B)

  – Right: Wiegelman's model extrapolation overlaid on a TRACE image

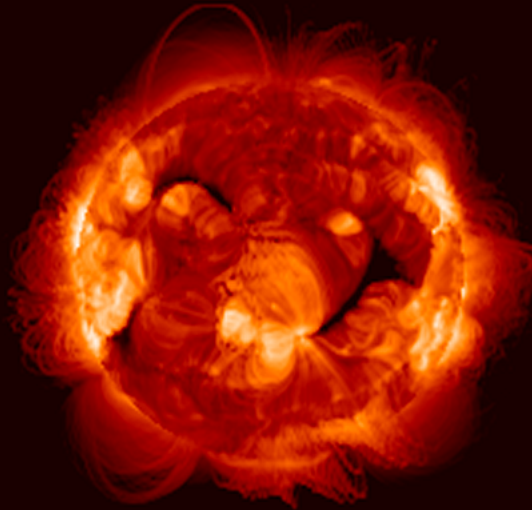- Goal: Determine Free Energy Stored in Pre-CME Magnetic Configuration
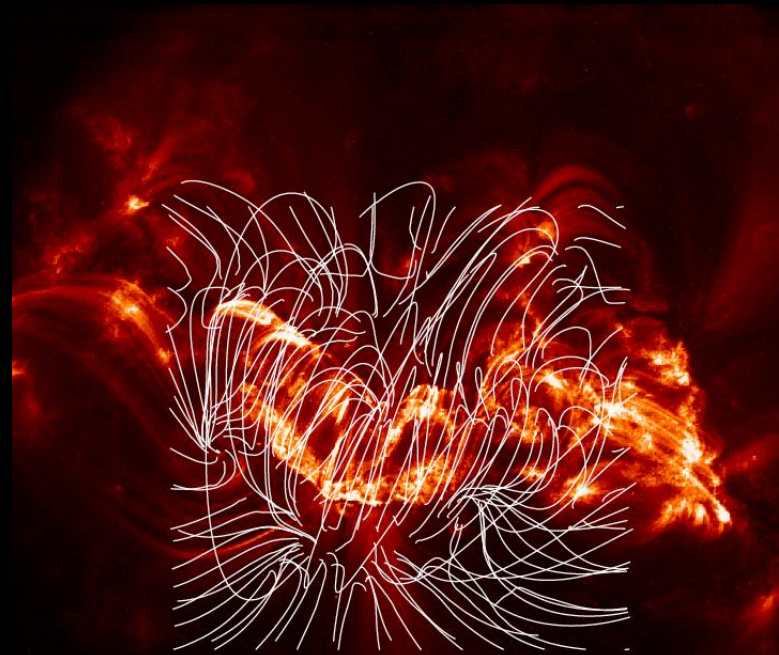
Tiepointing with 3 Eyes

- SECCHI will use tiepointing & triangulation to determine 3D structure of loops

- Reconstruction errors smaller with larger separation angles

- But more difficult to identify same loop at larger separation angles

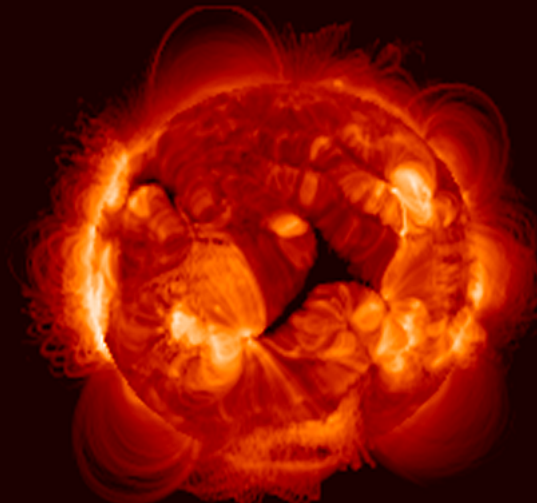- Third eye in the middle (Solar B or SOHO) will help identify same loop in STEREO A&B
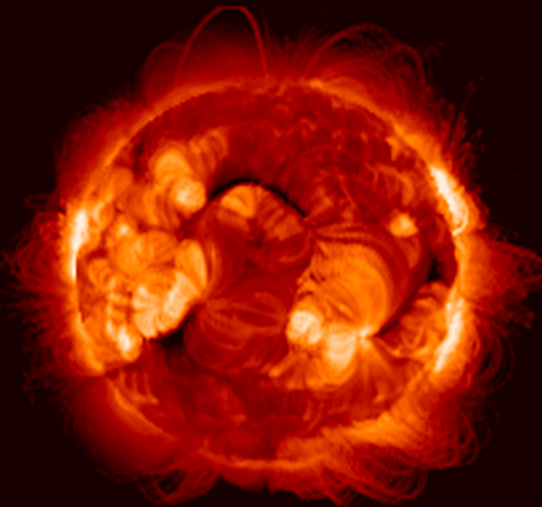
STEREO B at -22°   SOHO at 0°   STEREO A at 22°

Synthetic coronal images from Schrijver et al

Results from JPL Tiepointer Tool

- Reconstruction from synthetic SECCHI views with 44° separation

- Middle (Earth view) only used to help identify same loops

- 6 Loop segments could be identified, traced & reconstructed

Below: Side view of reconstructed loops used for verification

Red lines: successful automatic tracing & reconstruction from 6 initial tiepoints

-22°

+22°
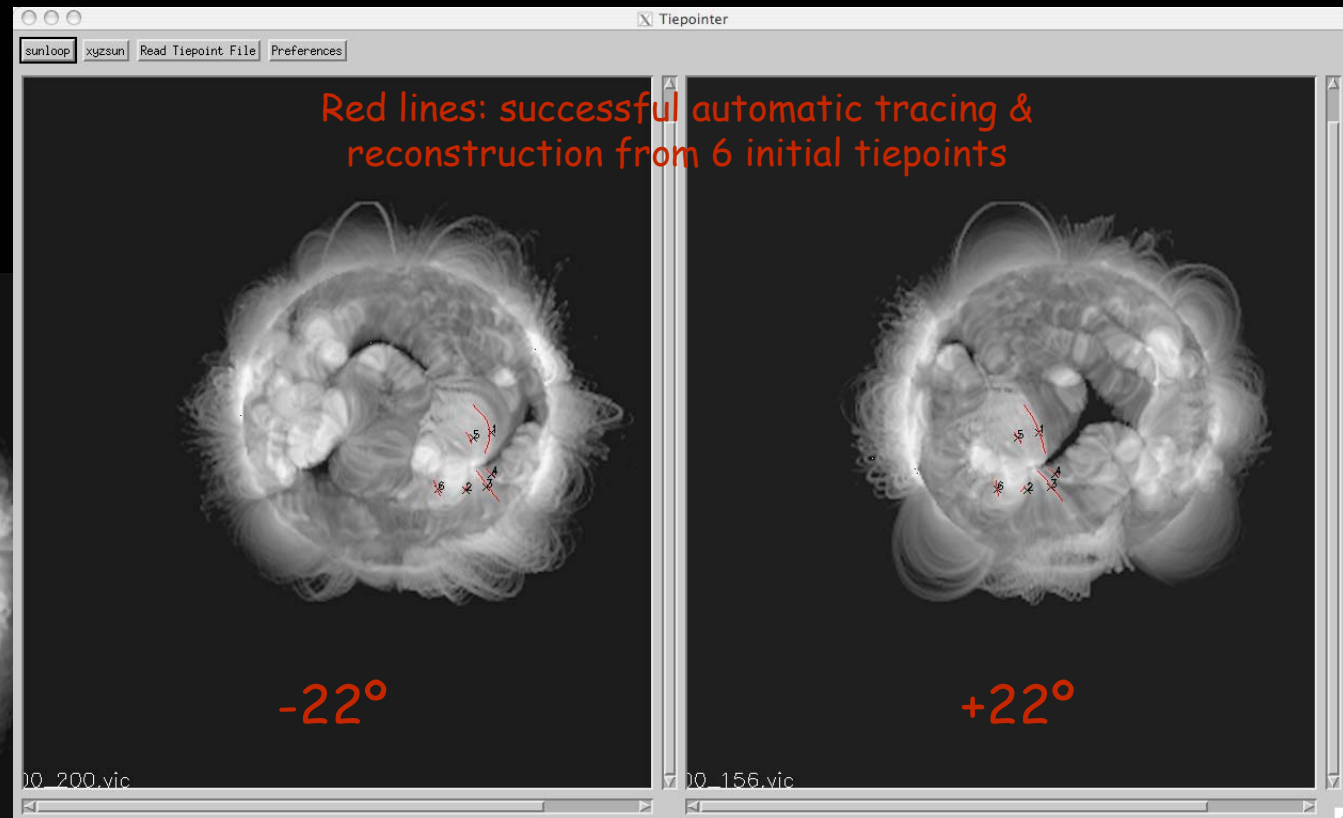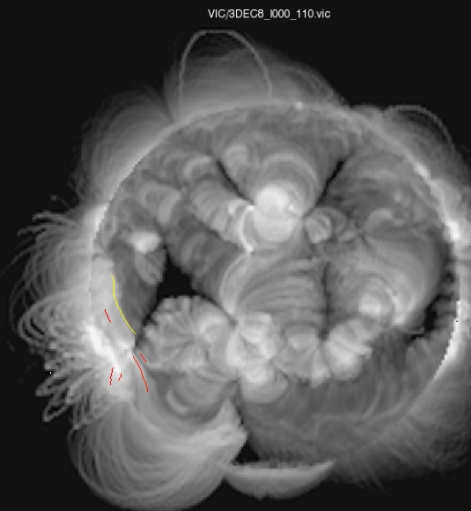
Summary

- Developed tool for 3D reconstruction of loops from STEREO / SECCHI pairs
  - Uses automatic feature tracking to trace loop segments in each image
  - Limited to cases where the same loop can be identified in both images
  - Limited to vertically oriented features due to horizontal stereo ambiguity
- Tested on SXT Virtual Corona dataset, courtesy K. Schrijver et al.
  - We find that it works over a broad range of separation angles of about 10 to 100 deg.
- Now uses synthetic SECCHI data with fits headers
- We are ready for other to start using it!

Backup

Synthetic EUVI Data Set with Fits Headers

NEW: Using this data, created synthetic *EUVI A&B data set with fits headers using SPICE ephemeris file*
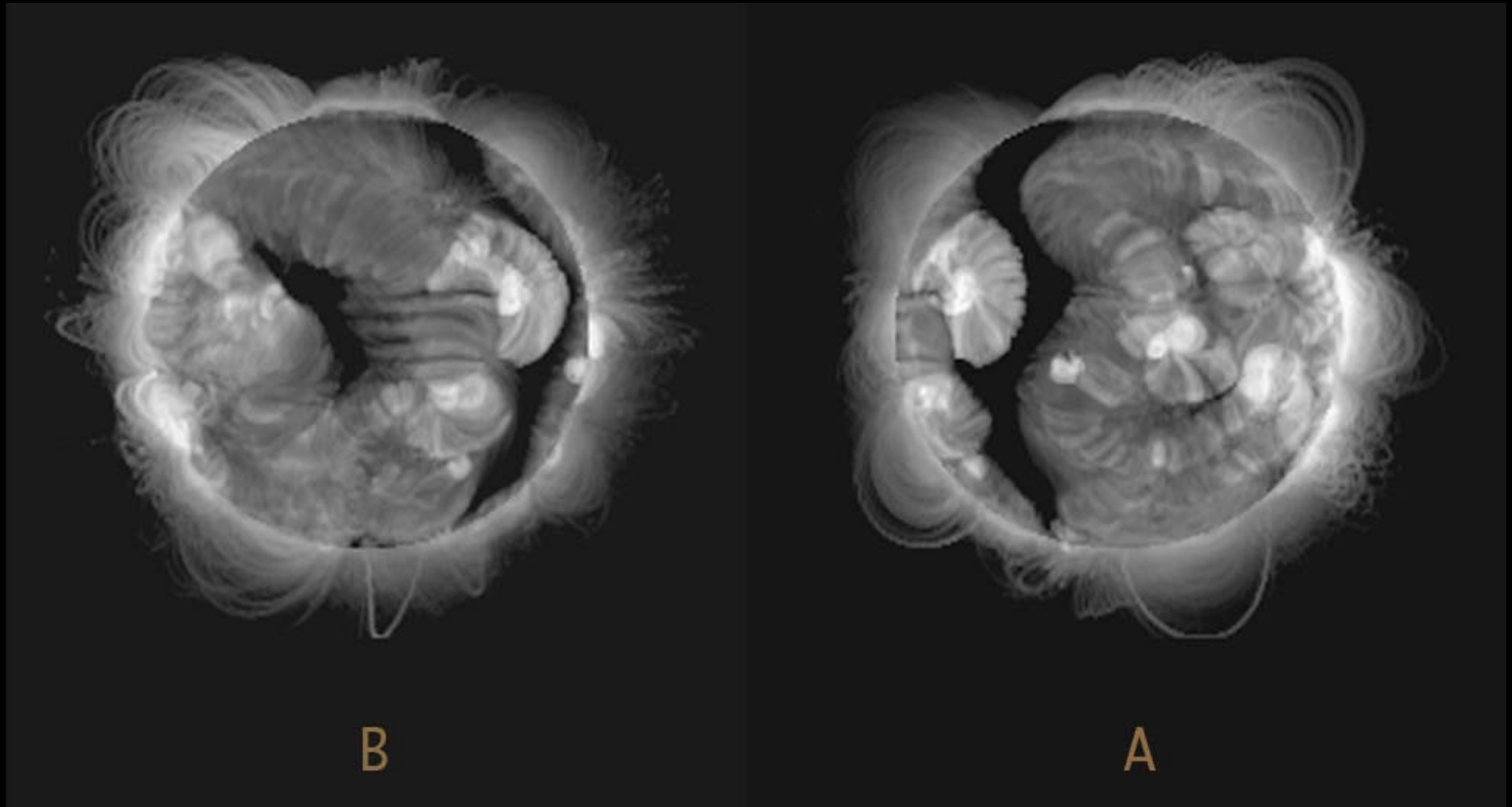
20080616104300peuB.fts
DATE_OBS='2008-06-16T10:43:00.000'

20080616104300peuA.fts
DATE_OBS='2008-06-16T10:43:00.000'

Method for loop tracing

Sunloop uses triangulation to the compute x,y,z coordinates (in the solar coordinate frame) and latitude & longitude information of a feature for a stereo image pair with known camera model.

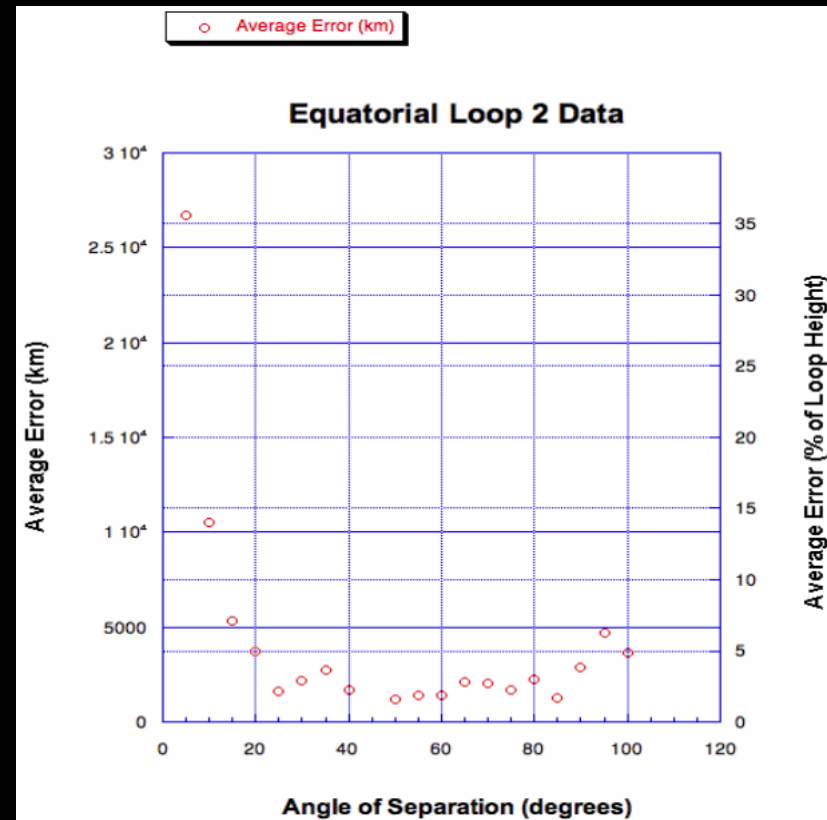The following steps are performed in tracing a loop:

1. Beginning with the user's seed points, the program searches a small area to locate the best quality point centered upon the loop. It prefers bright filaments but can also be configured to follow bright edges and other linear features.
2. Local direction (orientation) of the loop is calculated.
3. It then searches again in the direction of the loop for the best next quality point, and computes the new direction.
4. If that point passes the tests it is added to the segment. If not then growth stops in this direction.

Results for Reconstruction Error

Good stereoscopic reconstruction is possible
over a wide range of separation angles
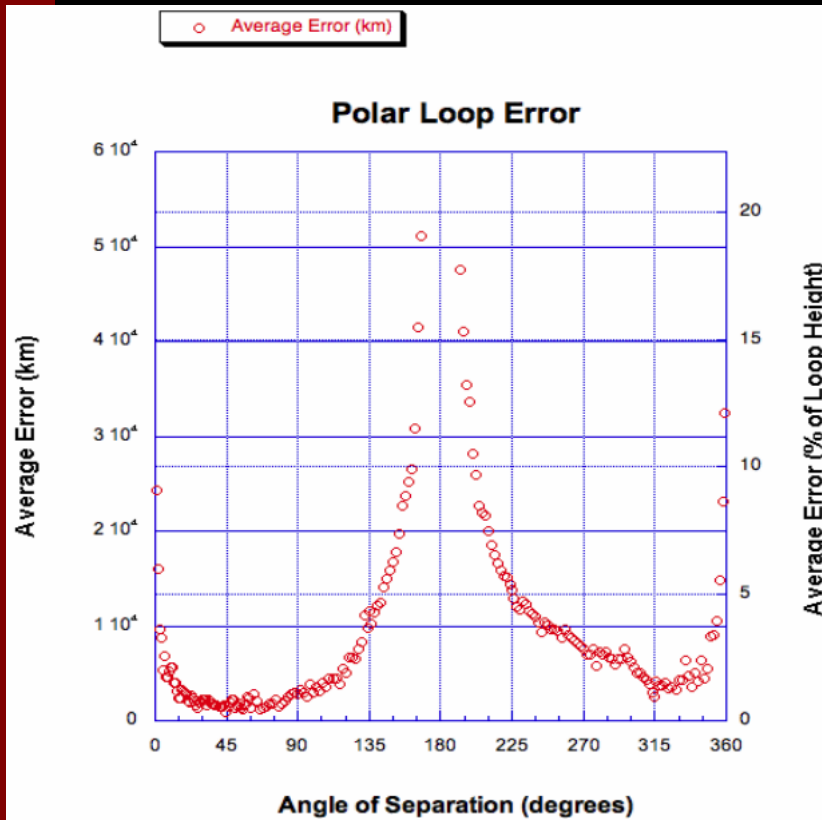
*Error vs. stereo angle for
polar loop (shown)*

*Error vs. stereo angle for an
equatorial loop (not shown)*

Method for finding 3D coordinates

The following steps are performed in determining the 3-d coordinates of points on the loop:

1. The ray vector for each point in the left profile is compared with the ray vector for every point in the right profile to generate an error (the miss distance of the two vectors).
2. The right point with the smallest error is, with it's 2 neighbors, used to estimate the line where the vectors cross. We use a quadratic model which gives results good to about 1/10 pixel.
3. The sample value of this line is computed from a spline model of the right profile.
4. The left point and the new sub pixel right point construct vectors which cross at the solar xyz value of interest.
5. This cross point (the 3D location) is written to the output file.

STEREO Angular Separation

STEREO Launch date:
February 11, 2006

10°
Sep 12, 2006

100°
Aug 15, 2008
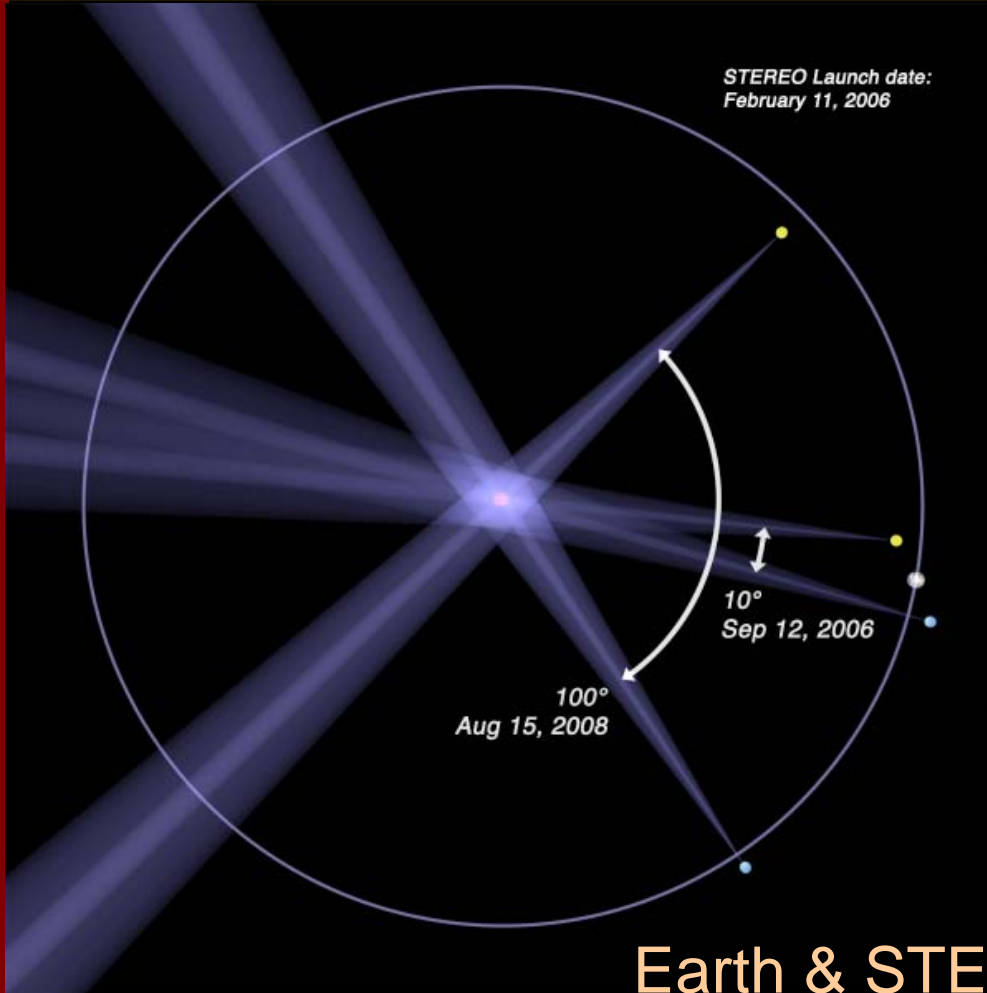
Earth & STEREO spacecraft for separations of 10º and 100º