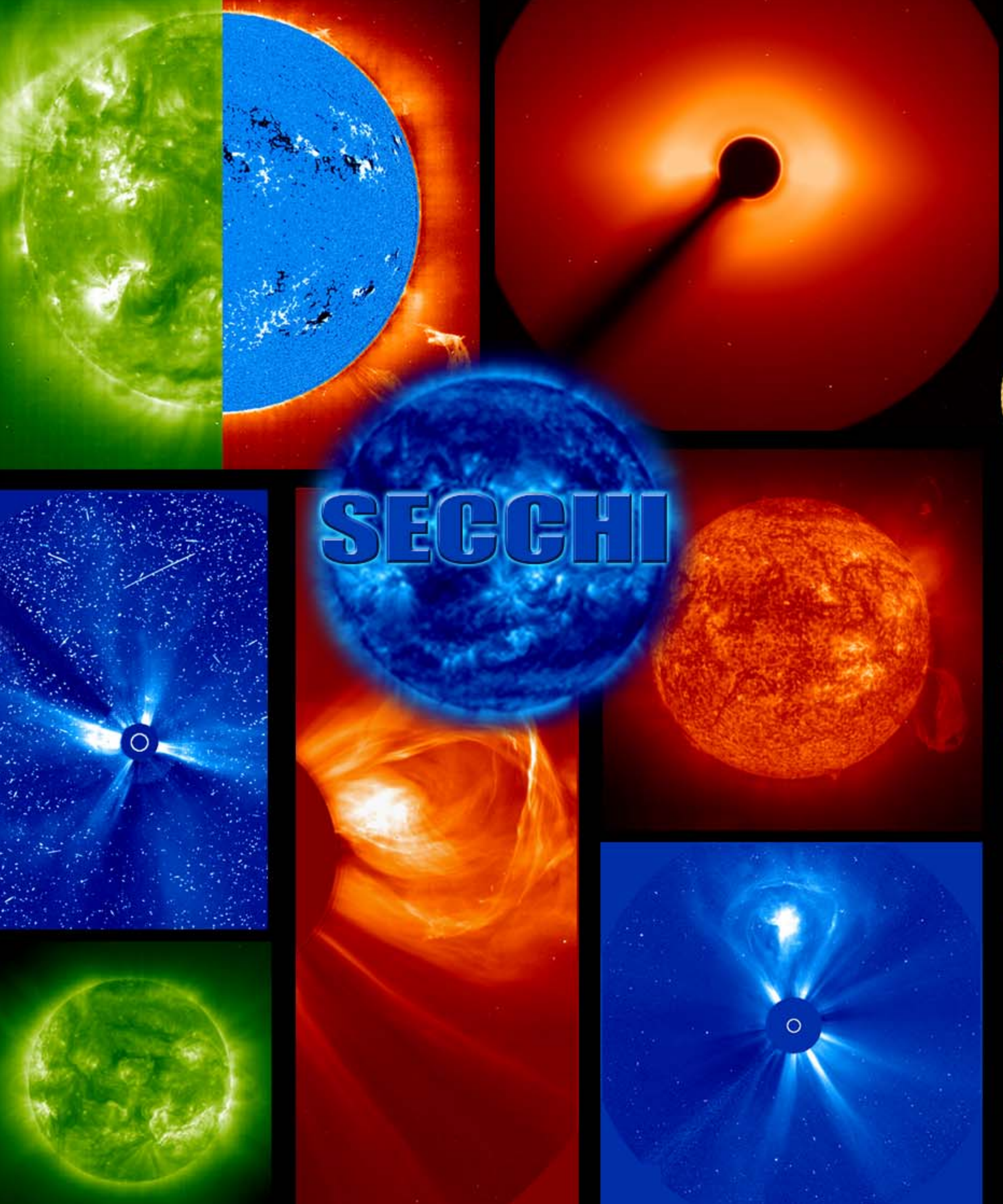
Sun Earth Connection Coronal & Heliospheric Investigation (SECCHI) Science Overview

Russell A. Howard

Principal Investigator

Naval Research Laboartory



Sun Earth Connection Coronal & Heliospheric Investigation (SECCHI)

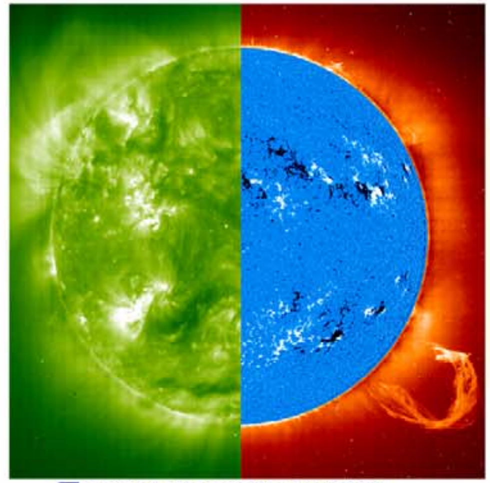
Critical Design Review (CDR)

November 4-6, 2002

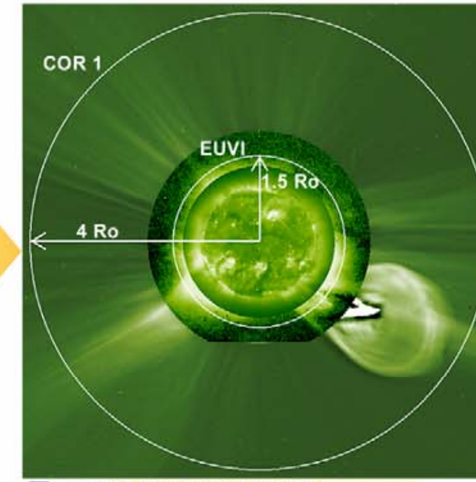
SECCHI Science Overview

SECCHI Exploration of CMEs and the Heliosphere on STEREO

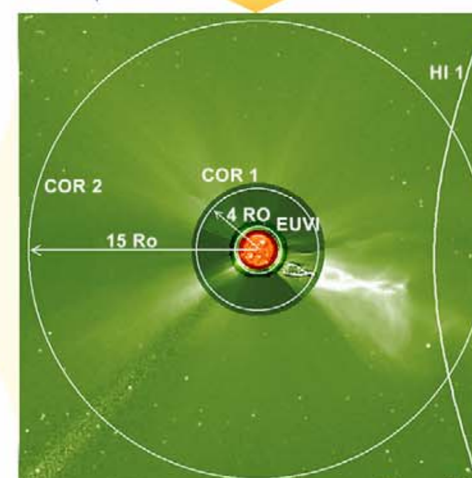
- *What Configurations of the Corona Lead to a CME?*
- *What Initiates a CME?*
- *What Accelerates CMEs?*
- *How Does a CME Interact With the Heliosphere?*
- *How do CMEs Cause Space Weather Disturbances?*



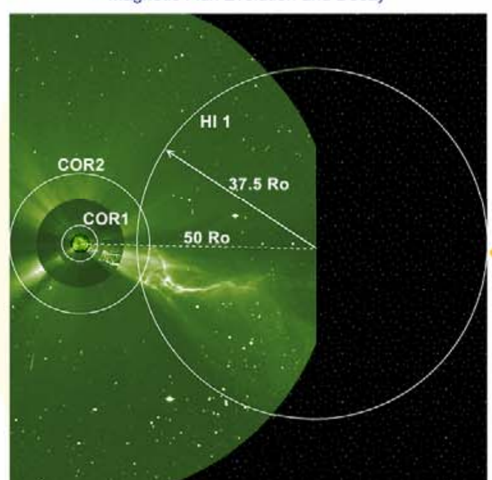
Explore the Magnetic Origins of CMEs
- Photospheric Shearing Motions
- Magnetic Flux Emergence
- Magnetic Flux Evolution and Decay



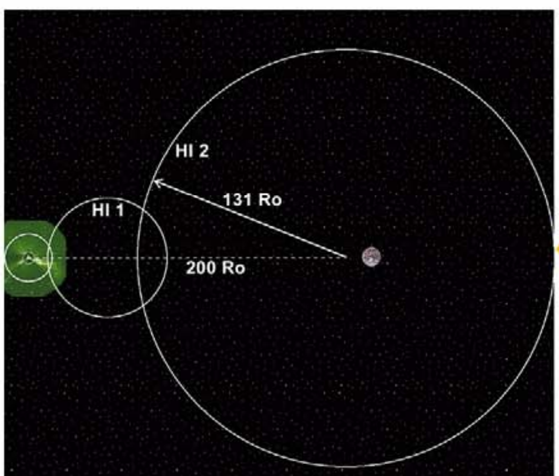
Understand the Initiation of CMEs
- Reconnection
- The Role of Plasma vs. Magnetic Field Effects
- Rapid vs. Slow Drivers



Study the Physical Evolution of CMEs
- Reconnection
- Continued Energy Input and Mass Ejection
- Effect on Helmet Streamers



Investigate the Interaction of CMEs With the Heliosphere
- CME Physical Signatures at 1 AU
- Generation of Shocks
- Acceleration of Charged Particles
- Interaction With Heliospheric Plasma Sheet & Co-Rotating Interaction Regions
- Interaction With Other CMEs



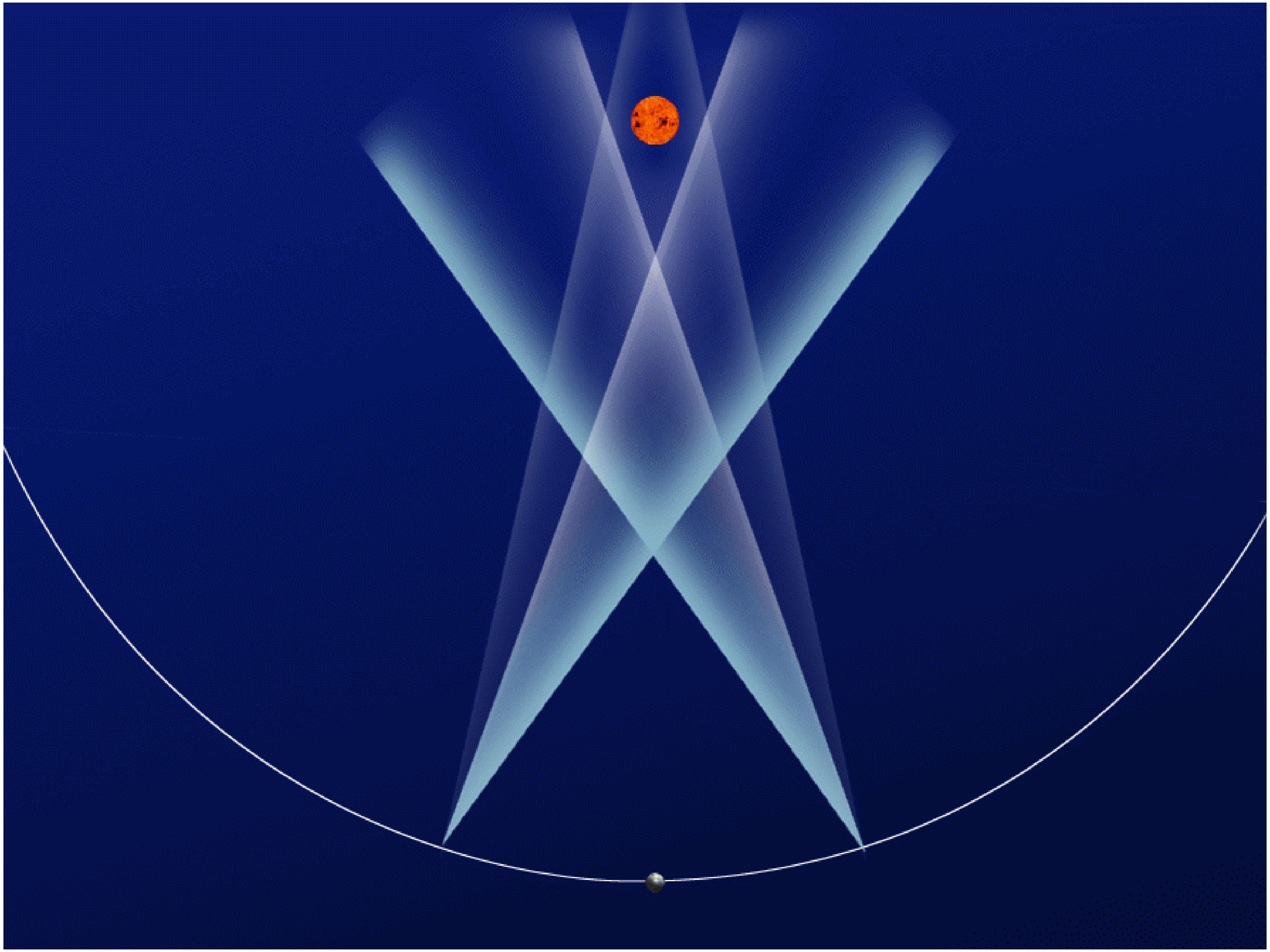
The Sun-Earth Connection: Understand the Role of CMEs in Space Weather
- Observe Trajectory of Earth-Directed CMEs
- Predict Arrival Time and Geo-Effectiveness of CMEs

Science From Two Spacecrafts

- STEREO Viewing
  - Simultaneous Vertical and Horizontal Views
  - Reveal 3-Dimensional Nature of Coronal Structures and CMEs

- Wide Separation
  - EUVI From One Spacecraft Sees Disk Signature of CMEs Seen As Limb From Other Spacecraft
  - Relate CMEs in White Light to *in Situ* Measurements
    - CORs and HI Observe CME in Limb View From One Spacecraft
    - Fields and Particles Observed From Other Spacecraft With White Light Observations From Other Spacecraft at Large Angles

Overlap of Views From HI1 and CORs



STEREO Level-1 Science Objectives

Measurement Requirement	STEREO Mission Science Measurement Requirements
1A	Determine CME Initiation Time to an Accuracy of Order 10 Min
1B	Determine Location of CME Initiation to Within ±5 Degrees of Solar Latitude and Longitude
2C	Determine Evolution of CME Mass Distribution and Longitudinal Extent to an Accuracy of ±5 Degrees
2D	Determine CME and MHD Shock Speeds Accurate to ±10% As It Propagates From Sun to Earth
2E	Determine Direction of CME and MHD Shock Propagation to Within ±5 Degrees of Latitude and Longitude
4J	Obtain Time Series of Solar Wind Speed Accurate to ±10% at Two Points Separated in Solar Longitude

Deriving SECCHI Requirements

- Level-1 Requirements Define:
  - Accuracy of Measuring Position, Intensity and Velocity of CMEs
  - Instrument and Spacecraft Pointing Accuracy and Stability
  - Positional Knowledge
  - Timing Knowledge
- These Impose Requirements on Spatial Resolution, Intensity Resolution and Range, Timing Accuracy, Exposure Timing, EUV Filters, etc.

SECCHI Instrument Performance Requirements

	EUVI	COR1	COR2	HI-1	HI-2
Telescope FOV (deg)	≥ 0.90	≥ 2.13	≥ 8.00	≥ 20.0	≥ 69.2
Occulter Size (deg)	N/A	S/C A: ≤ 0.75 S/C B: ≤ 0.68	S/C A: ≤ 1.34 S/C B: ≤ 1.22	N/A	N/A
Bandpass (nm)	Fe IX: 17.1 Fe XII: 19.5 Fe XV: 28.4 He II: 30.4	[650, 750]	[650, 750]	[650, 750]	[400, 1000]
Spatial Resolution (arcsec)	≤ 3.5	≤ 16.0	≤ 30.0	≤ 140	≤ 486
Intensity / Brightness Range (I/I0, B/B0)	Fe IX: [2.39e-4, 0.477] Fe XII: [3.23e-4, 0.645] Fe XV: [4.11e-3, 0.821] He II: [1.0e-3, 1.000]	[2.0e-9, 1.0e-6]	[2.0e-11, 6.0e-9]	[1.0e-12, 9.0e-11]	[1.0e-13, 6.0e-12]
Intensity / Brightness Resolution (I/I0, B/B0)	Fe IX: 1.2e-4 Fe XII: 1.6e-4 Fe XV: 4.1e-4 He II: 5.0e-4	≤ 2.0e-9, 5.0e-10 at FOV edge	≤ 8.0e-11, 1.0e-12 at FOV edge	≤ 6.0e-14, 5.0e-15 at FOV edge	≤ 2.0e-15, 5.0e-16 at FOV edge
Exposure Time Range (sec)	Fe IX: [0.1, 14.0] Fe XII: [0.1, 20.0] Fe XV: [15.0, 30.0] He II: [7.0, 25.0]	[0.1, 1]	[1, 8]	[10, 30]	[40, 70]
Image Sequence Specification	2 EUV emission line images at 2 different wavelengths	3 white light images at 3 different polarization angles	3 white light images at 3 different polarization angles	70 white light images	50 white light images
Image Sequence Acquisition Time	≤ 60 sec	≤ 12 sec	≤ 45 sec	≤ 38 min	≤ 64 min
Image Sequence Cadence	≥ 1 min	≥ 1 min	≥ 5 min	≥ 47 min	≥ 102 min

Collaboration With Other Instruments

- SWAVES
  - Location of CMEs in IP Space
  - Source Region of Radio Emission
  - Electron Density Determination
  - Extent of CMEs
  - Propagation of CMEs
- SOHO/SDO
  - Third Eye for 3D Reconstruction

- IMPACT and PLASTIC
  - Source Region of Energetic Particle Generation
  - Relation of in-Situ Particles to Large-Scale CME Structures
  - Extent of CMEs

Changes Since PDR Affecting SECCHI Science

- **Keep Within Cost Cap, We Had to Descope Science Co-Is During FY02 and FY03; This Will Reduce the Readiness of the Modeling Efforts As They Apply to SECCHI/STEREO at Launch**
- **Increase (5%) in Telemetry Allocation Enables Higher Cadences**
  - **Better Observations of CME Timing**
  - **Better Observations of Initial Configurations of Corona Prior to and After CME**
  - **Higher Accuracy of CME Speed Determination**
- **Establishment of Campaigns Permits Very High Cadence Observations of Specific Low Coronal Processes**

SECCHI U.S. Partners

- Hardware/Software Providers
  - Naval Research Laboratory+*
  - Lockheed Martin Advanced Technology Center+
  - NASA/Goddard Space Flight Center+
  - Praxis, Inc
  - HYTEC, Inc.
  - Swales, Inc.
  - The Hammers Co.
- DoD Funding Partner
  - USAF Space Test Program

- MHD Modeling / Visualization Providers
  - Boston College+
  - Jet Propulsion Laboratory+
  - Science Applications Inc.*
- Additional Co-I Support
  - Harvard-Smithsonian Astrophysical Observatory
  - Southwest Research Institute
  - University of Michigan

Notes: * = MHD Modeling   + = 3D Modeling/Visualization

SECCHI European Partners

- Belgium
  - Centre Spatial de Liege, Liege #
  - Observatoire Royale de Belgique, Bruxelles *+
- France
  - Institute d'Astrophysique Spatiale, Orsay #
  - Observatoire de Paris, Meudon *
  - Institute d'Optique, Orsay #
  - Laboratoire d'Astronomie Spatiale, Marseille +
  - Universite d'Orleans, Orleans *
- Germany
  - Max-Planck-Institut für Aeronomie, Lindau +*#
  - University of Kiel, Kiel #
- United Kingdom
  - University of Birmingham, Birmingham #
  - Rutherford Appleton Laboratory, Didcot #
  - Mullard Space Science Laboratory, London +

Notes: * = MHD Modeling   + = 3D Modeling/Visualization   # = Hardware Provider

SECCHI Data Products

- **Data and Analysis Tools – Will Be Included in SOLARSOFT Library Available to Community**
- **Images, Movies, Synoptic Maps**
- **Space Weather Information (e.g., Beacon Data)**
- **CME Lists (Automatic CME Recognition)**
- **Comet/Asteroid Lists**
- **Database/Web Interfaces (e.g. Solar Virtual Observatory Interface)**

- **Product Details Are Under Discussion by Science Team Including How to Simultaneously Display Other Instrument Data**

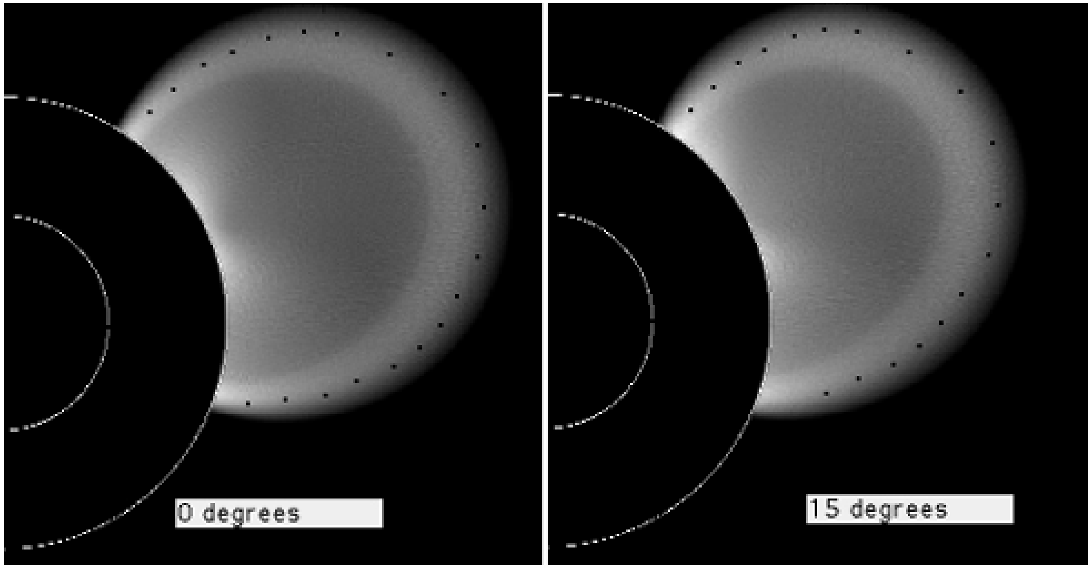
SECCHI Data and Analysis Tools

- Calibration Procedure (Photometric, Geometric)
- Removal of Energetic Particle Tracks
- Structure Measurements
- Movie Generation Tool
- Potential B Field Calculation Tool
- Emission Measure Map Tool
- Image Visualization Tools (Single/Multiple Instrument)
- Three-Dimensional Image Reconstruction
- CME Propagation Modeling Tool
- Available to Community Through SolarSoft

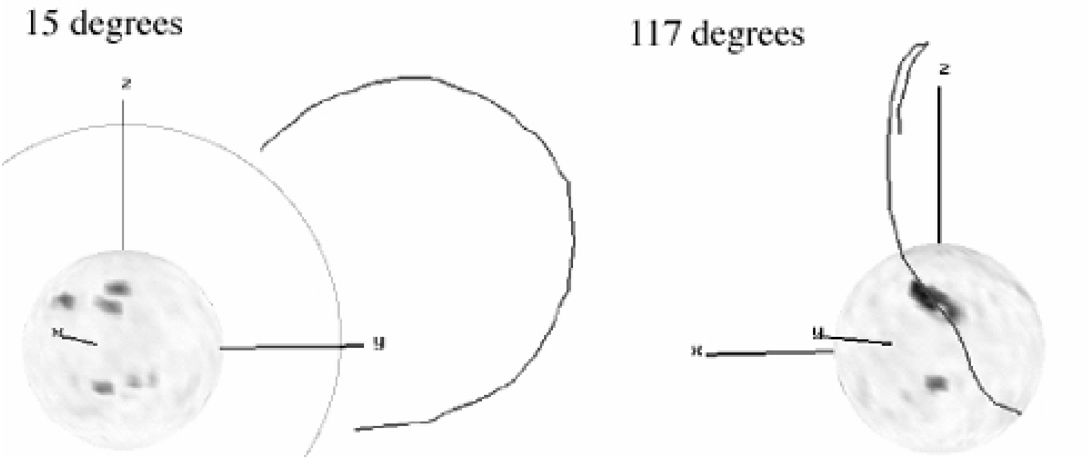
SECCHI MHD Modeling

- **Essential to Interpret SECCHI Observations and to Connect Them to the *in-Situ* and Radio Wave Observations**
- **3 Broad MHD Objectives:**
  - **Model the Quasi-Static Plasma Parameters**
  - **Investigate the Physics of the Initiation of CMEs**
  - **Propagate a Transient Structure Into the Heliosphere**
- **These Model Outputs Will Be Available As Boundary Values to New Codes for Predicting Solar Wind Properties, Energetic Particles, and Radio Emission**

Example of CME Analysis Using Stereographic Tie-Point Technique



Tie Line

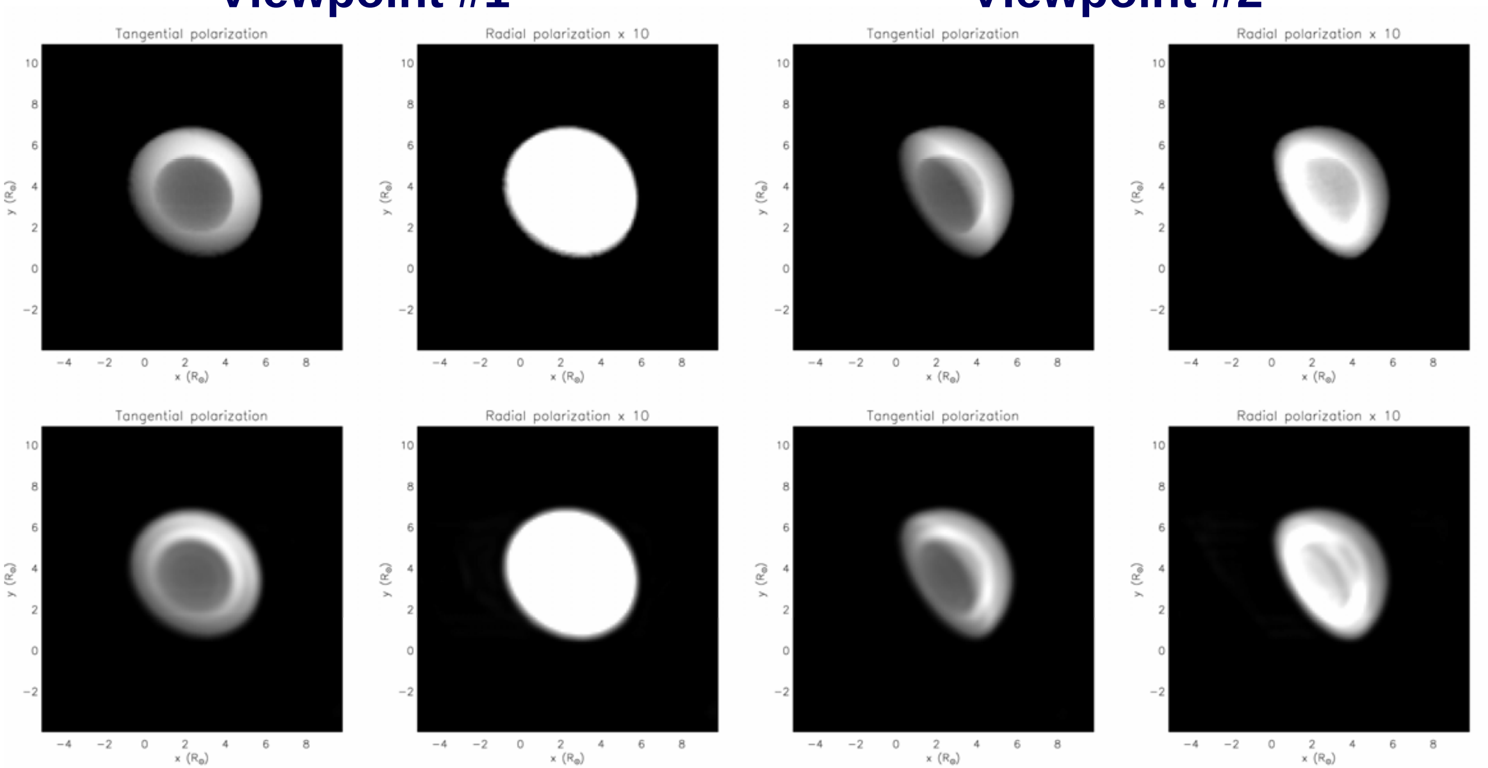


Example of 3D Reconstruction

Viewpoint #1 **Viewpoint #2**

Input

Output



p_t p_r p_t p_r

See Poster in Lobby