



HELCATS

WP 3

Deriving/cataloguing the kinematic properties
of STEREO/HI CMEs based on geometrical and
forward modelling

Overview

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HELCATS Kick-Off Meeting, 14-15 May 2014, RAL, Didcot, UK



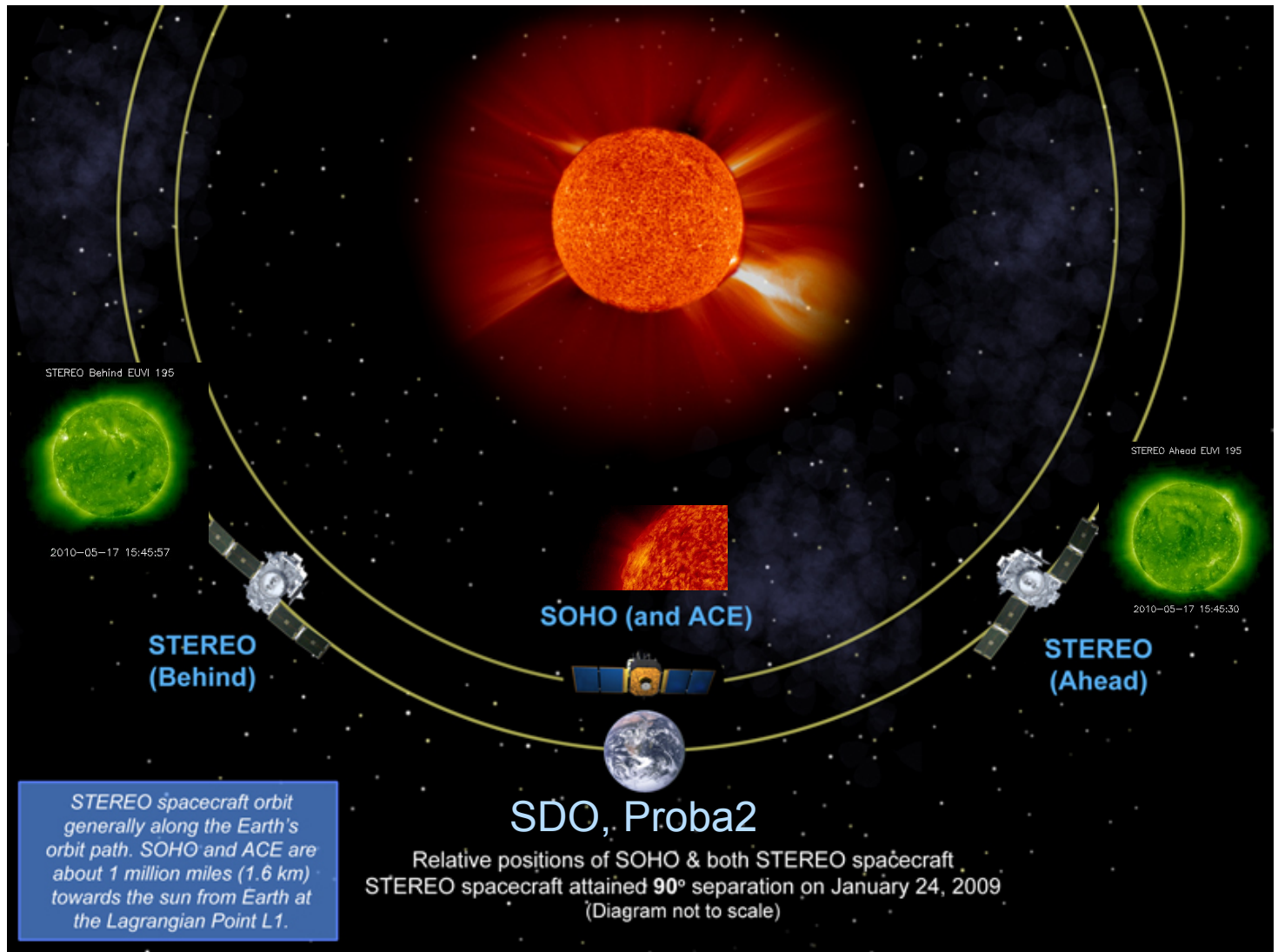


WP 3 - Objectives

- To obtain the kinematic properties for the STEREO/HI CMEs in the catalogue established in WP2, through application of geometrical and forward-modelling techniques to the HI data
- To augment the STEREO/HI CME catalogue with the model results, and supply those results as input for comparisons with coronal source and in-situ observations in the validation of WP4
- To update the STEREO/COR2 CME catalogue, initiated under the SOTERIA FP7 project, until the end of 2011 (including the application of forward modelling to the appropriate CMEs)
- To compare the results from the geometrical and forward modelling of HI CMEs with the modelling results for COR2
- To prototype the use of inverse modelling to derive typical HI CME parameters (speed, size, mass), for photospheric and low coronal source regions typically associated with CMEs



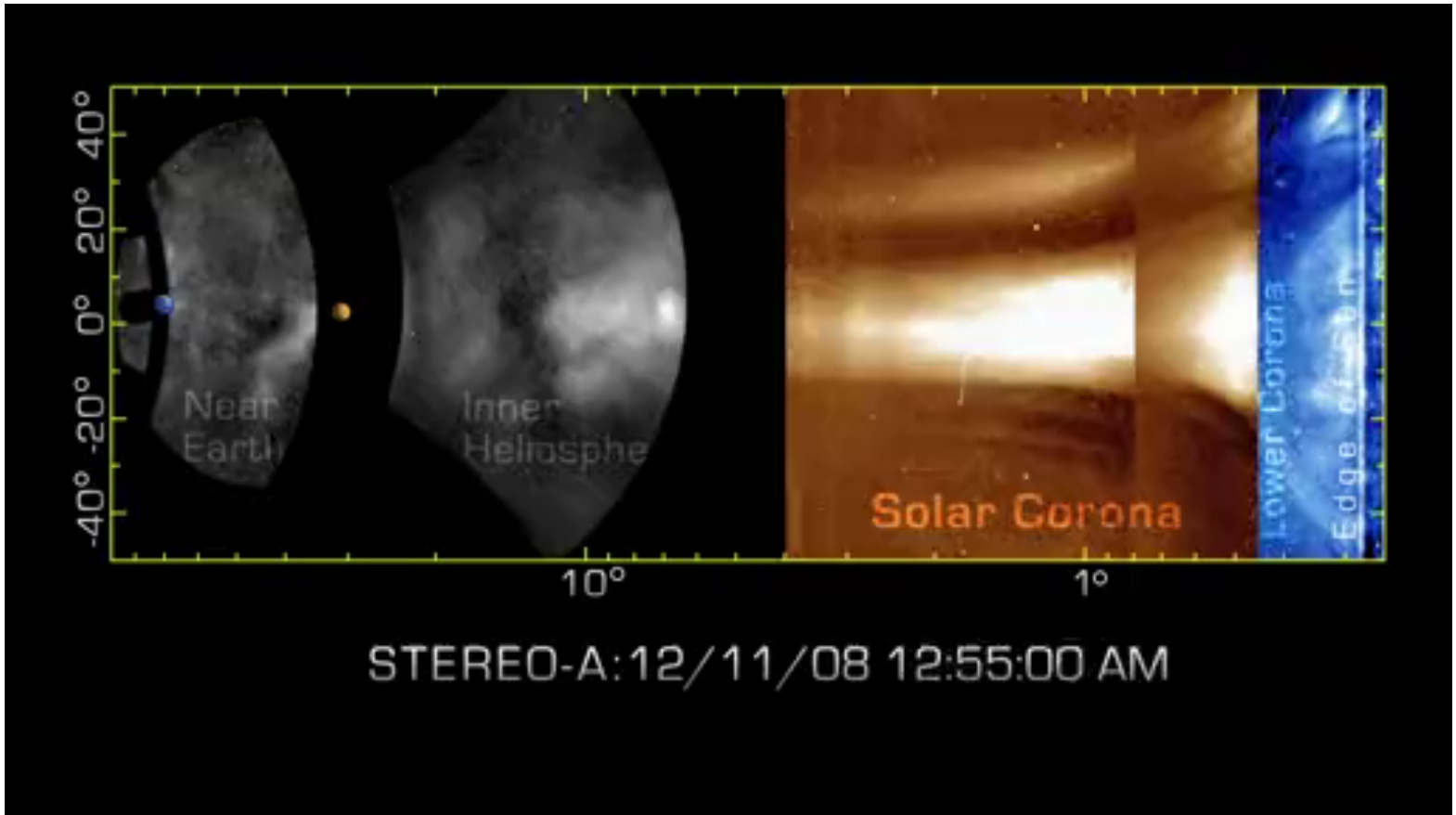
Multipoint observations



Credits: NASA/STEREO/SECCHI

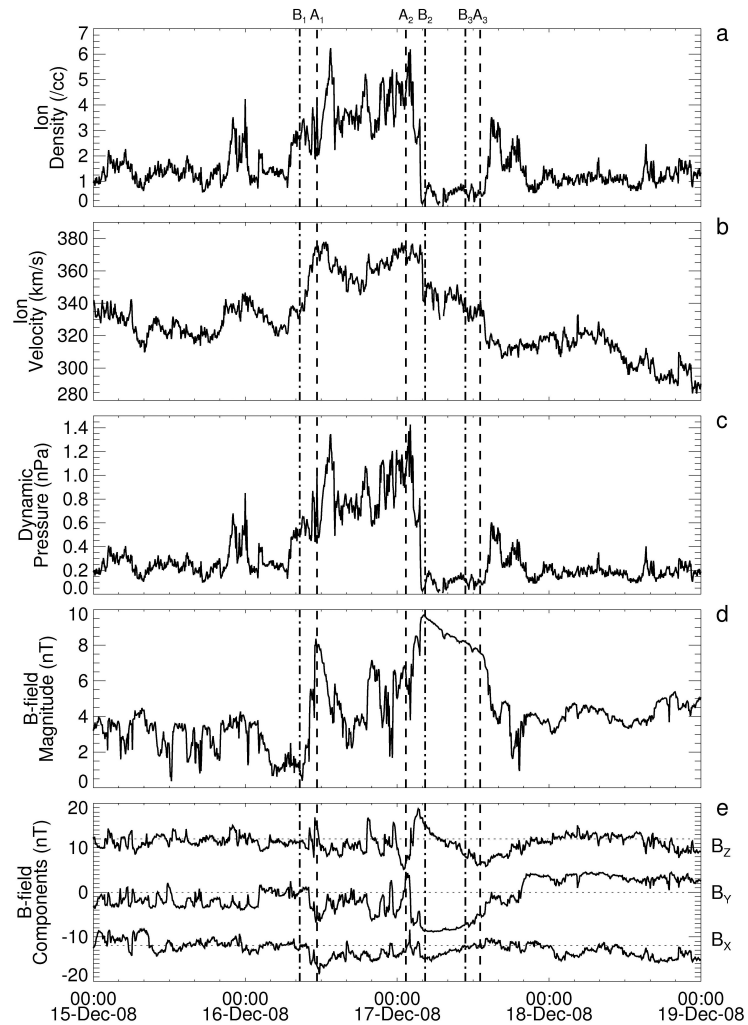
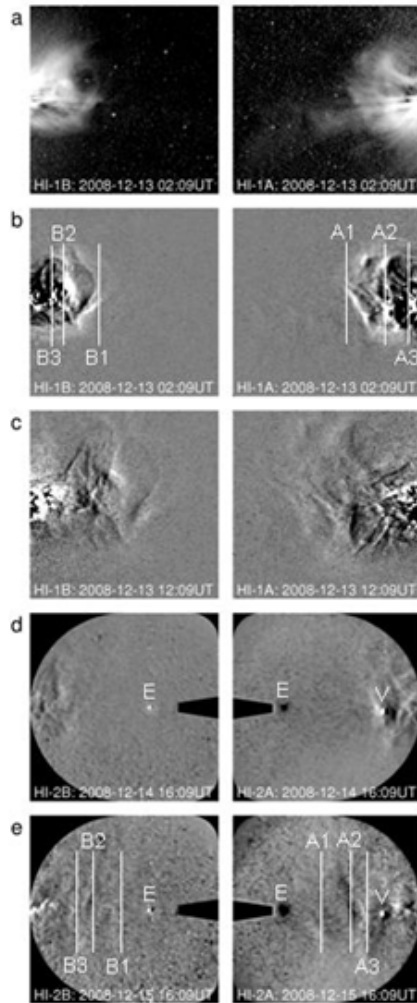


CME – Sun to Earth Tracking



Credits: NASA/STEREO/SECCHI

CME – HI Tracking and In-Situ Measurements

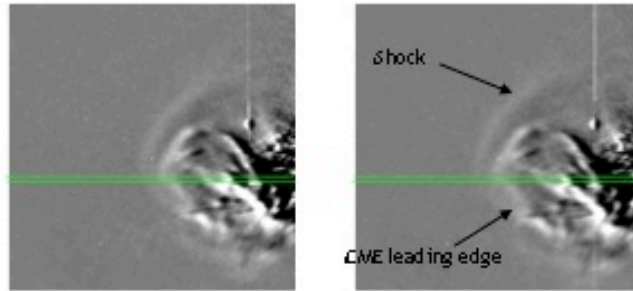


Davis et al., 2009



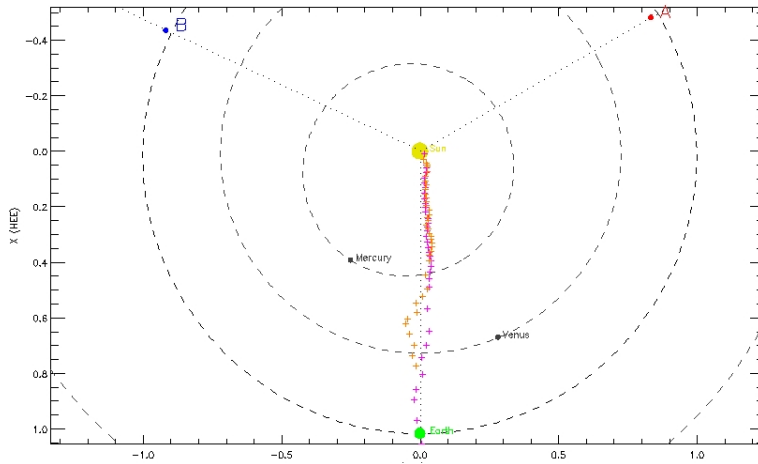
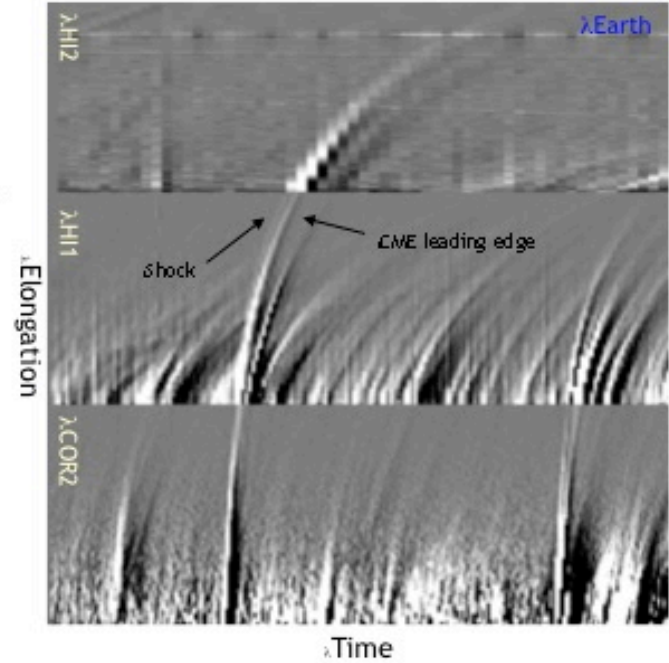


Time-elongation (J) maps



.03/04/2010T19:29
Stereo A - HI1

.03/04/2010T20:09
Stereo A - HI1

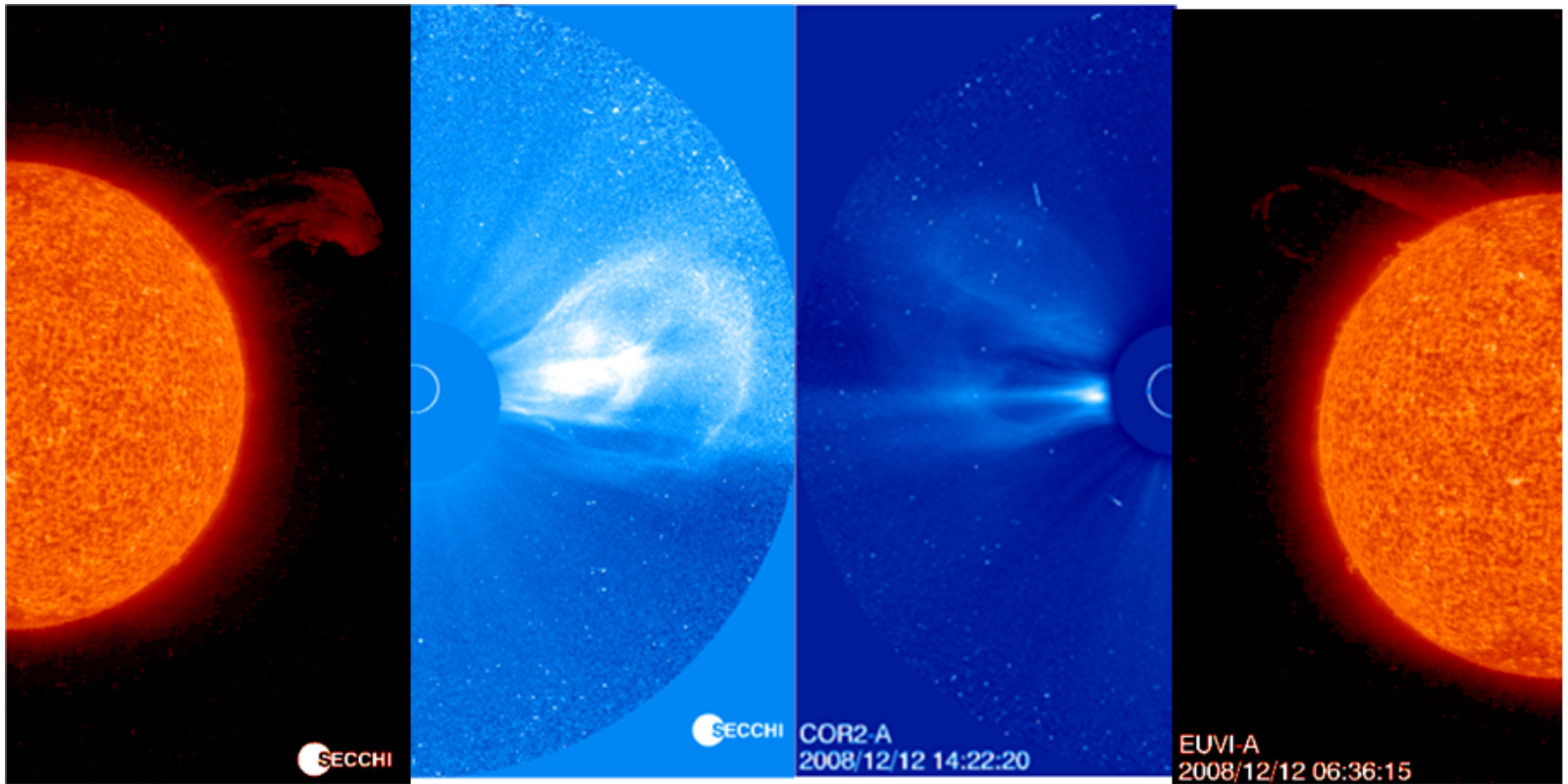


J-map technique;
Courtesy: L. Volpes

Courtesy: L. Volpes, J. Davies



STEREO SECCHI/EUVI A, B 304 Å and COR 2 A, B Observations

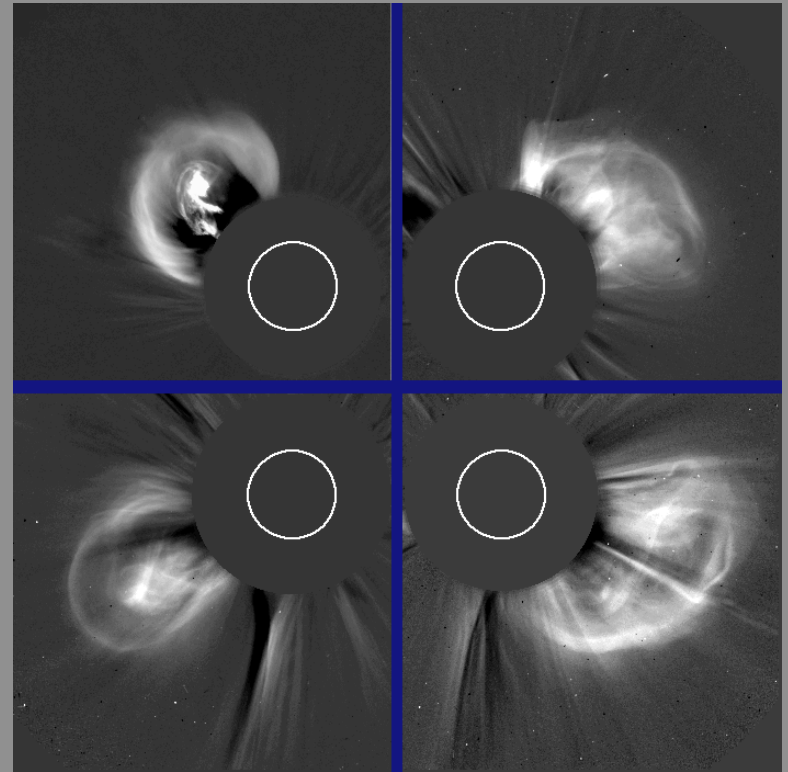
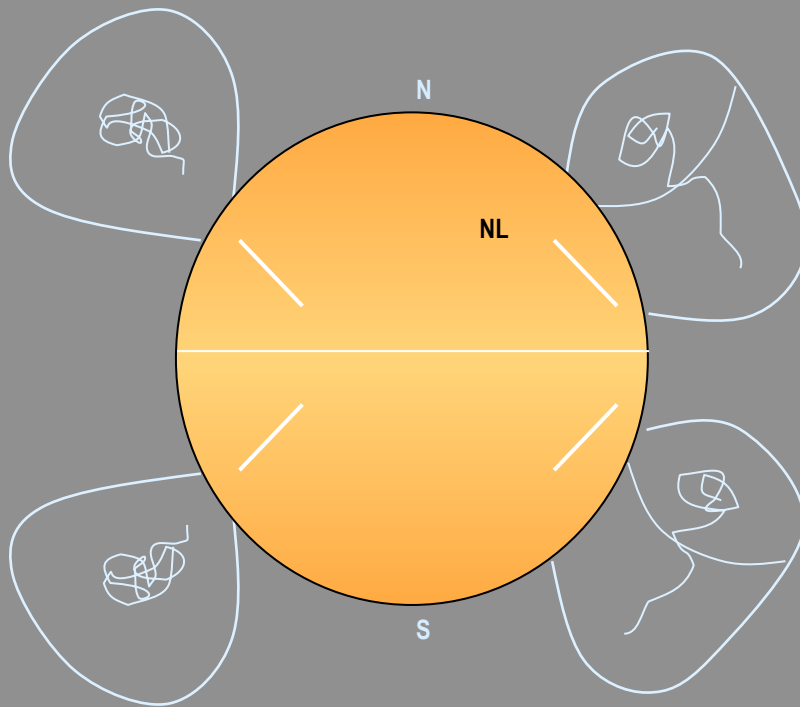




Basic Scheme Explaining the 3D Structure of CMEs

The WL coronagraph observations of CMEs can be modelled through large-scale magnetic flux ropes which properties depend on the magnetic source region characteristics.

Joy's & Hale's laws



Cremades & Bothmer, A&A 2004

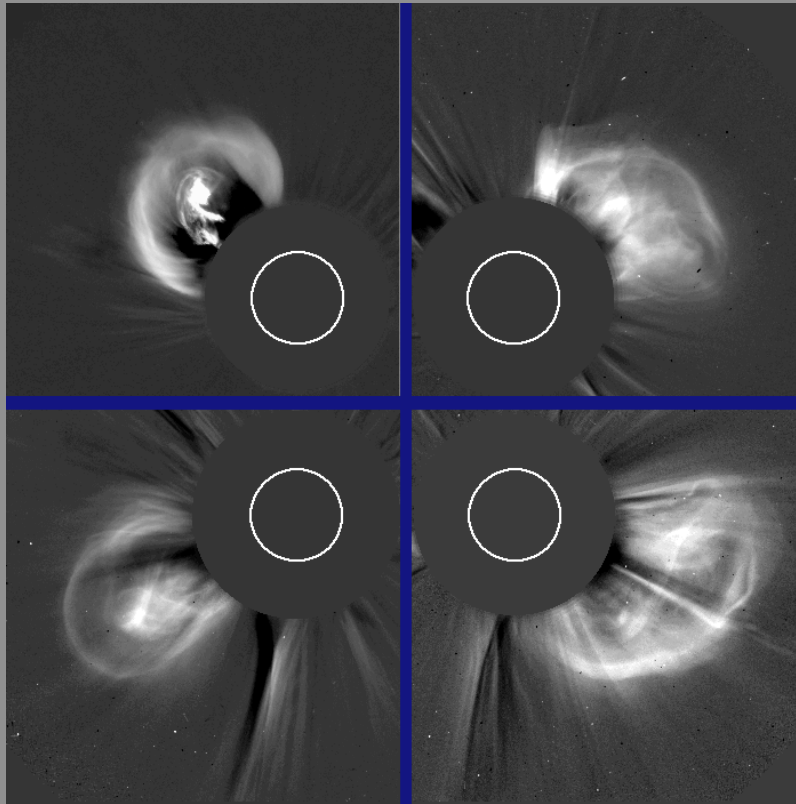
SOHO/LASCO C2





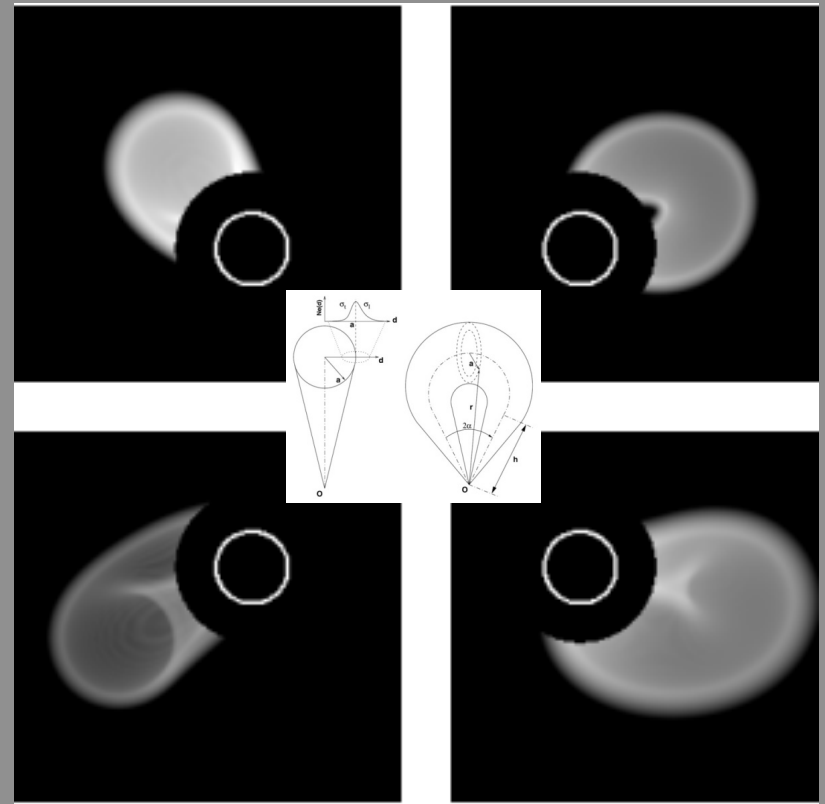
Modelling the Electron Density Distribution

LASCO Observations



Cremades & Bothmer, A&A 2004

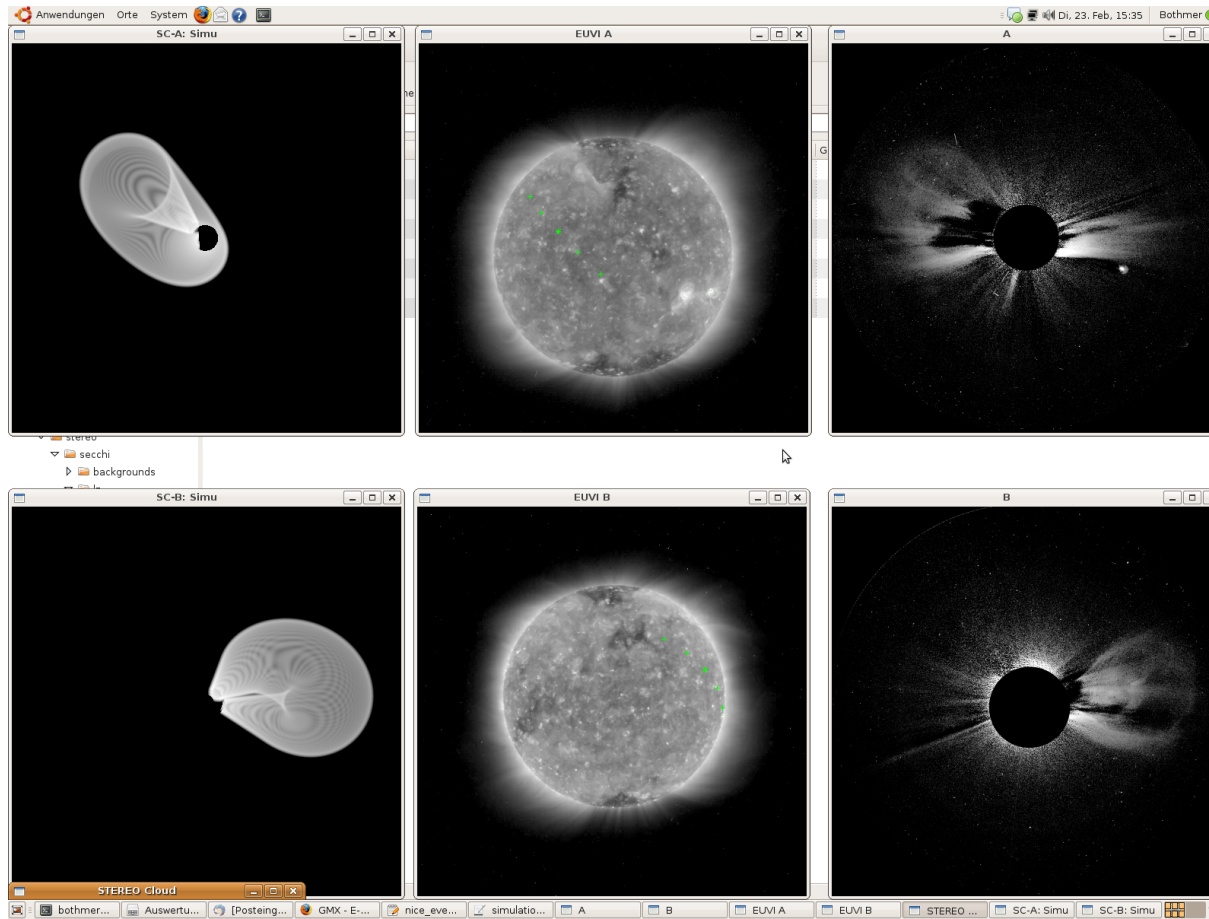
Simulations (GCS-Modell, $\int n_e dV$)



Howard, Thernisien and Vourlidas, ApJ 2006



CME GCS Forward Modelling



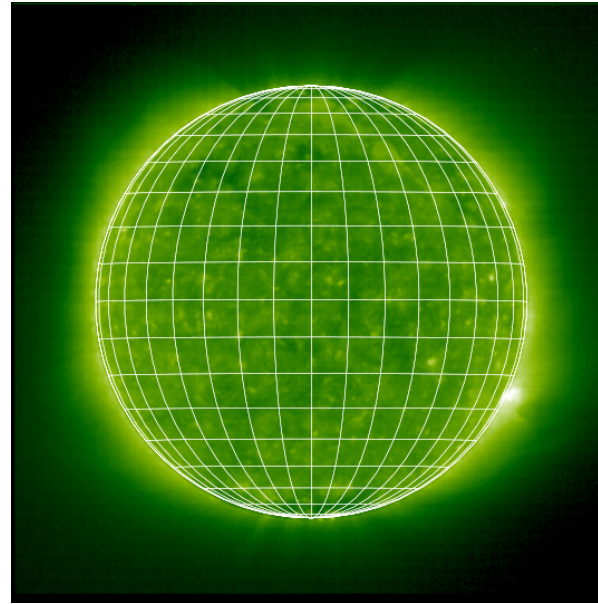
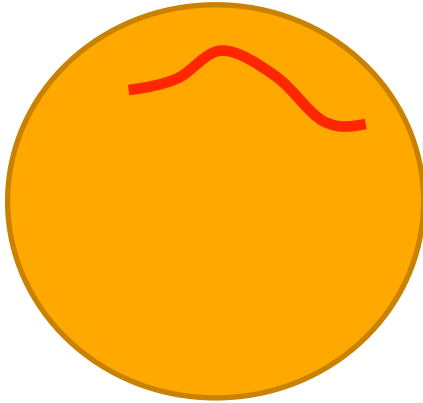
SR:

CLON = 81°

CLAT = N10

$\theta = +42^\circ$

Low Coronal Signatures

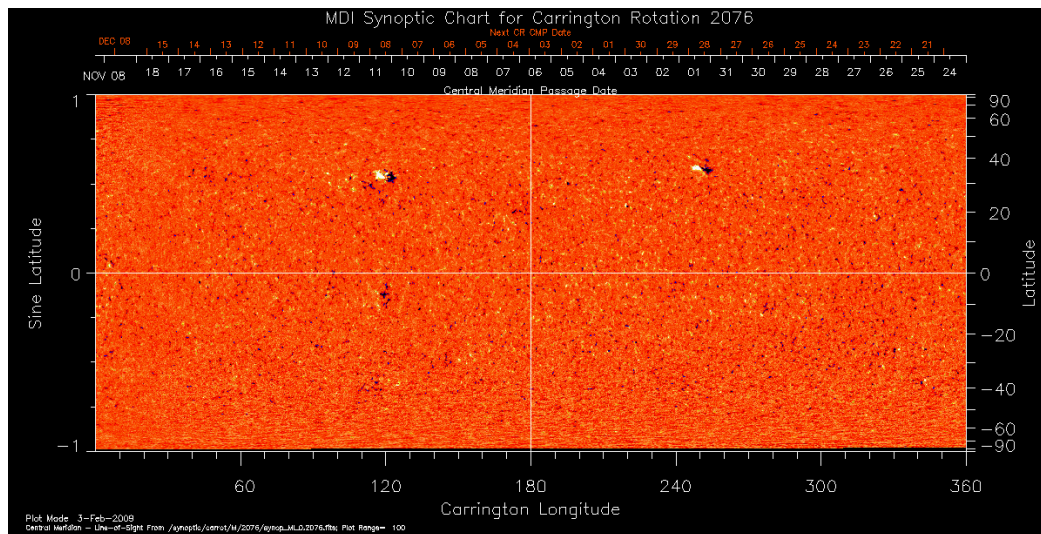
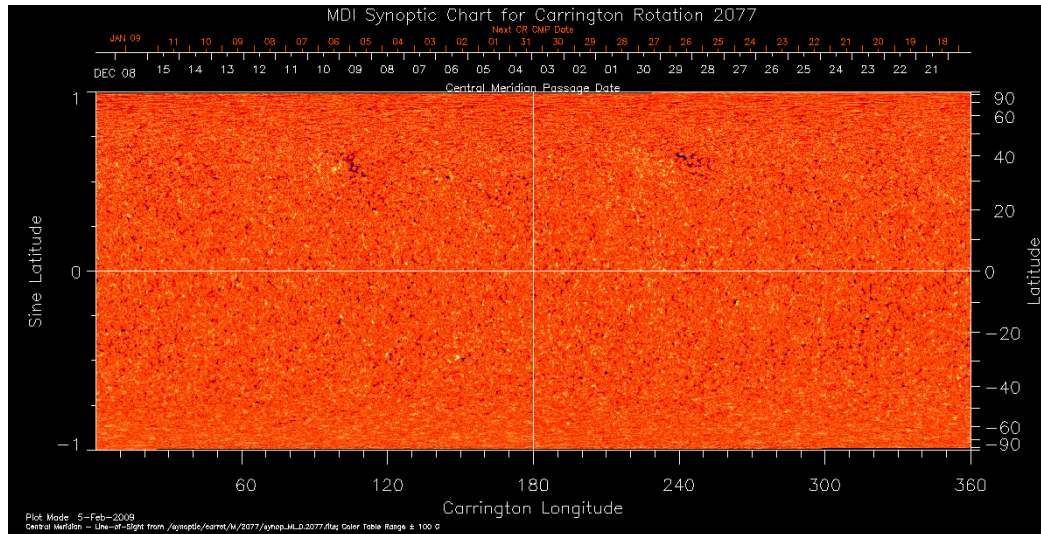


Estimated onset time:
December 12, 08 UT

PEA on December 12,
12 UT



Photospheric Source Region



Bosman, Bothmer, et al. 2012



WP 3 – Task Summary (UGOE 21, TCD 15, STFC 9, UNIGRAZ 6)

- **Task 3.1: Geometrical modelling of STEREO/HI CMEs (Task leader: STFC; Additional participant: UNIGRAZ)**
Instruments used: STEREO/HI
Role of participants: STFC: J-map provision/CME extraction; STFC and UNIGRAZ: geometrical modelling application and development
- **Task 3.2: Forward modelling of STEREO/HI CMEs (Task leader: UGOE)**
Instruments used: STEREO/SECCHI/HI, COR2
Role of participants: This task will be undertaken by UGOE.
- **Task 3.3: Inverse modelling of STEREO/HI CMEs (Task leader: UGOE; Additional participant: TCD)**
Instruments used: STEREO/SECCHI/HI, COR2
Role of participants: UGOE: modelling; TCD: source region input expertise.
- **Task 3.4: Comparison of modelling results (Task leaders: RAL, UGOE; Additional participant: TCD)**
Instruments used: STEREO/SECCHI, SOHO/MDI, SDO/HMI
Role of participants: RAL will collate, with input from all participants.





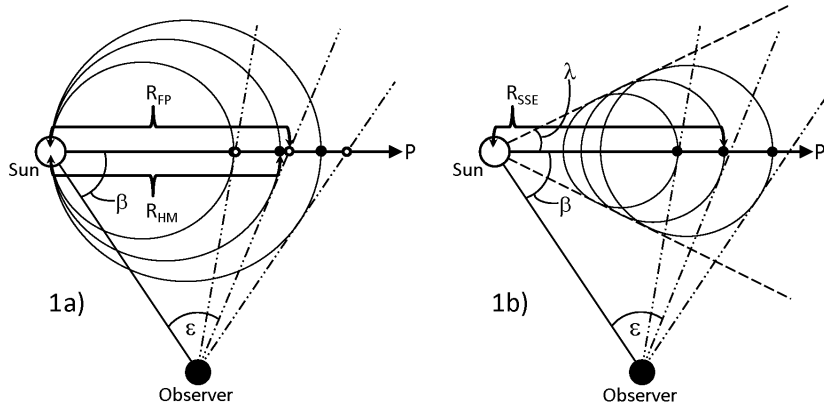
Task 3.1 - Geometrical modelling of STEREO/HI CMEs

Task leader: STFC; Additional participant: UNIGRAZ

- Geometrical modelling of the STEREO/HI CMEs identified and catalogued in WP2
- Creation of J-maps for backward (to source regions) and forward extrapolations (for solar system applications)
- Derivation of CME kinematic properties (propagation speed, direction and potentially size, launch time, source region location) and augmentation of the CME catalogue with these results (for comparisons with WP4 tasks 4.1 SR and 4.2 in-situ)
- Compilation of a catalogue of CME arrival time estimates at Mercury, Venus, Earth, Mars and Saturn as support to European-funded space missions around these planets.
- Integration of the catalogues in AMDA, offering access to the catalogues to the community of planetary scientists that use the European Research infrastructure (EUROPLANET)

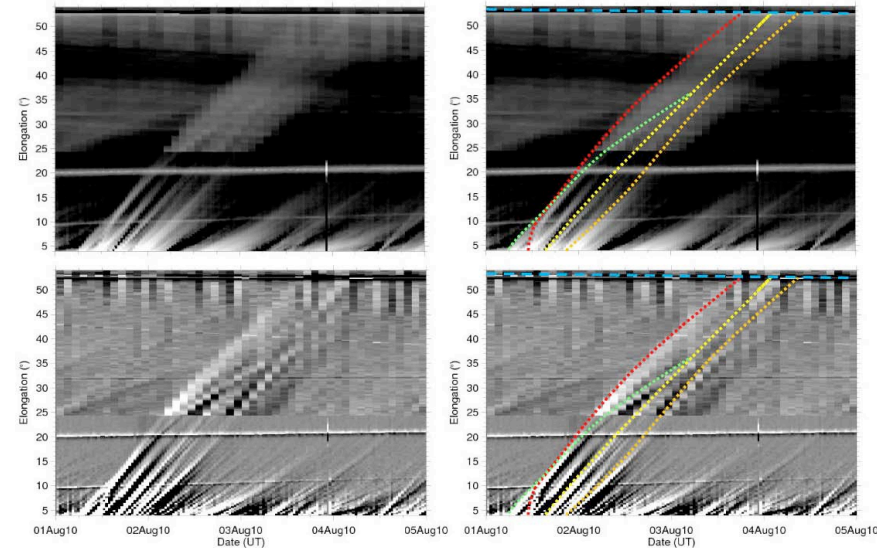


Task 3.1 - Geometrical modelling of STEREO/HI CMEs



The geometry of the FP, HM and SSE models (from Davies et al. 2012). The FP (HM) model is indicated by the black dots (large circles) in (a). (b) shows the SSE model. ϵ denotes elongation, β is the propagation angle relative to the Sun-observer line.

Time-elongation maps (J-maps; see Davies et al. 2009) showing a sequence of CMEs launched on 1st August 2010. Observations taken in the ecliptic plane are presented. Upper frames show background-subtracted data; lower frames use an image difference technique. Right-hand frames are overlaid with the CME tracks that were used to extract kinematic properties using FP and HM models (from Harrison et al. 2012).



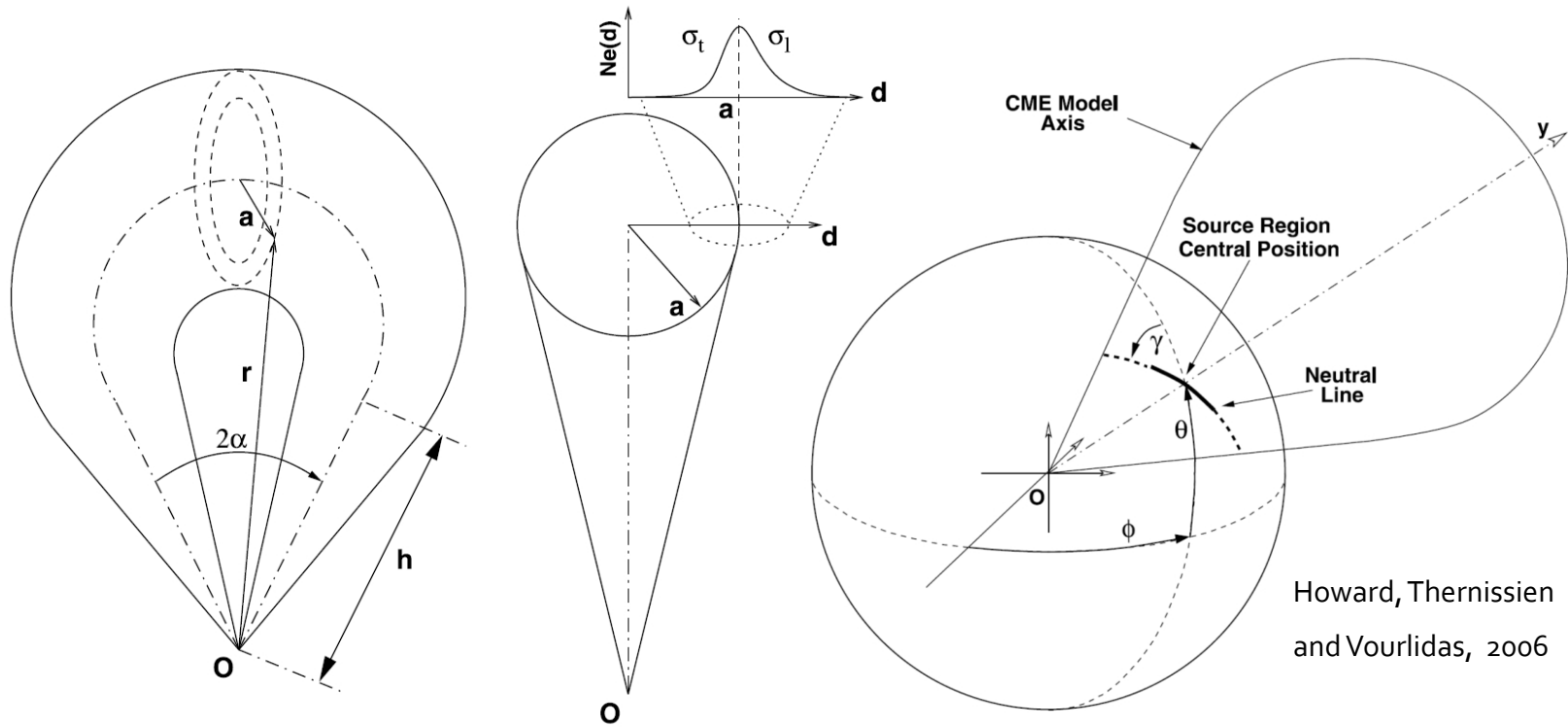


Task 3.2 - Forward modelling of STEREO/HI CMEs (Task leader: UGOE)

- GCS (Graduated Cylindrical Shell) modelling of the STEREO/HI CMEs of the WP2 catalogue
- Augmentation of CME catalogue with the derived parameters - CME geometries, speeds, propagation directions and mass estimates, including update of the COR 2 catalogue until end of 2011
- Calculation of back-projected launch time/location and forward-projected arrival time estimates at various solar system locations and inclusion of information into CME catalogues



Geometry of Graduated Cylindrical Shell (GCS) Model



Howard, Thernissien and Vourlidas, 2006

Parameter and electron density distribution

2α	angle between both legs		
h	height of the legs	Φ	longitude
h_{front}	distance between O (sun center) & leading edge	θ	latitude
a	radius of cross-section	γ	tilt angle
r	distance between sun center & boundary point of GCS		
$\kappa = a/r$	aspect ratio	σ_t	Gaussian width of density profile inside GCS
N_e	electron density	σ_l	Gaussian width of density profile outside GCS



UGOE COR 2 CME List

Selection Criteria

- based on clarity of CME appearance in COR2 FOV ($2.5 - 15 r_s$)

Best-Of CMEs

- List with 264 events established

CME- Modeling

- 242 Best-of CMEs studied through GCS modeling (Thernisien, Howard, Vourlidas, 2006)
- based on 3-D concept for CMEs (derived by Cremades & Bothmer, 2004)





Task 3.3 - Inverse modelling of STEREO/HI CMEs (Task leader: UGOE; Additional participant: TCD)

- Prototype the use of inverse modelling to derive typical parameters (speed, size and mass) for the CMEs in the CME catalogue (speed, size and mass) for photospheric and low coronal source regions





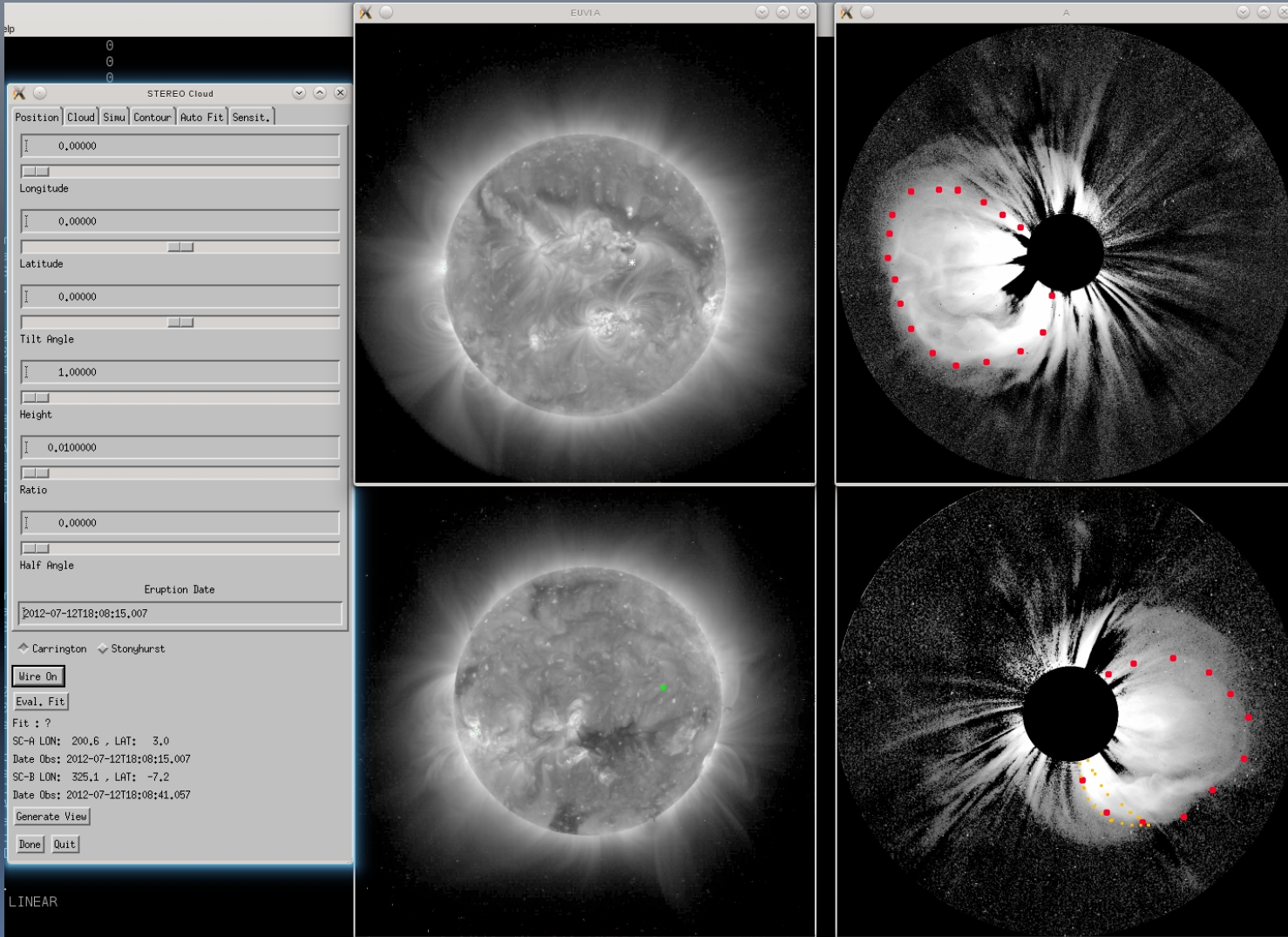
Task 3.3 - Inverse modelling of STEREO/HI CMEs (Task leader: UGOE; Additional participant: TCD)

The screenshot displays the STEREO cloud software interface. On the left is a file tree with a selected folder containing various data files. The central control panel includes input fields for Position (79.3800), Longitude (6.70660), Latitude (-67.6404), Tilt Angle, Height (0.551114), Ratio (24.3171), and Half Angle. It also features a 'Wire Off' button and a 'Fit : ?' section with parameters for SC-A and SC-B. The right side of the interface is divided into four panels: 'EUVI A' (top-left) and 'A' (top-right) showing a solar disk and a coronal image with green CME structures, respectively. The bottom row shows 'EUVI B' (bottom-left) and 'B' (bottom-right) with similar views. The bottom status bar indicates the current image size (1600 x 1200 Pixel) and a zoom level of 105%.

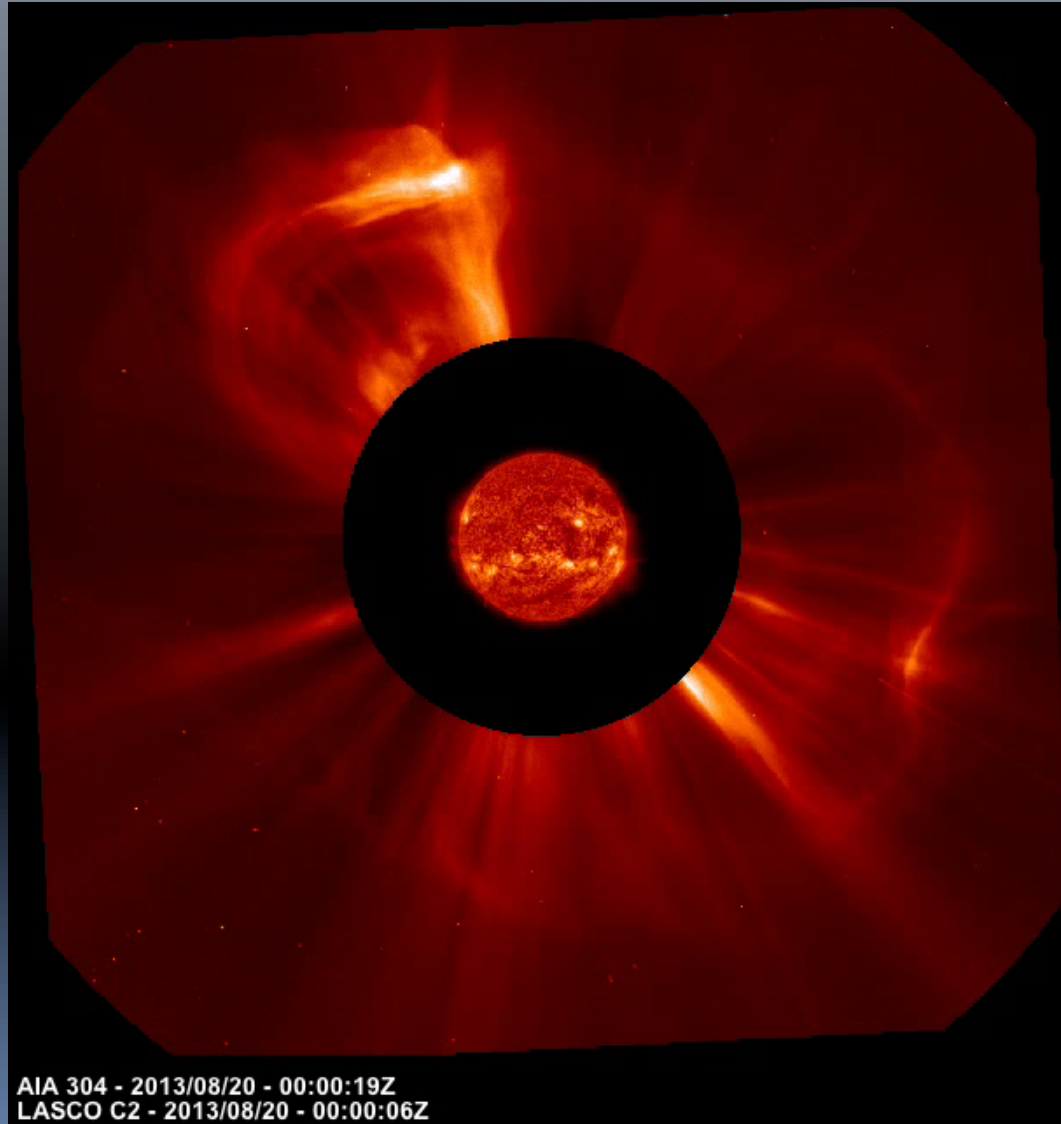


FR Modeling Complications

Shock fronts ahead of CMEs



Distorted CME front - SOHO/LASCO



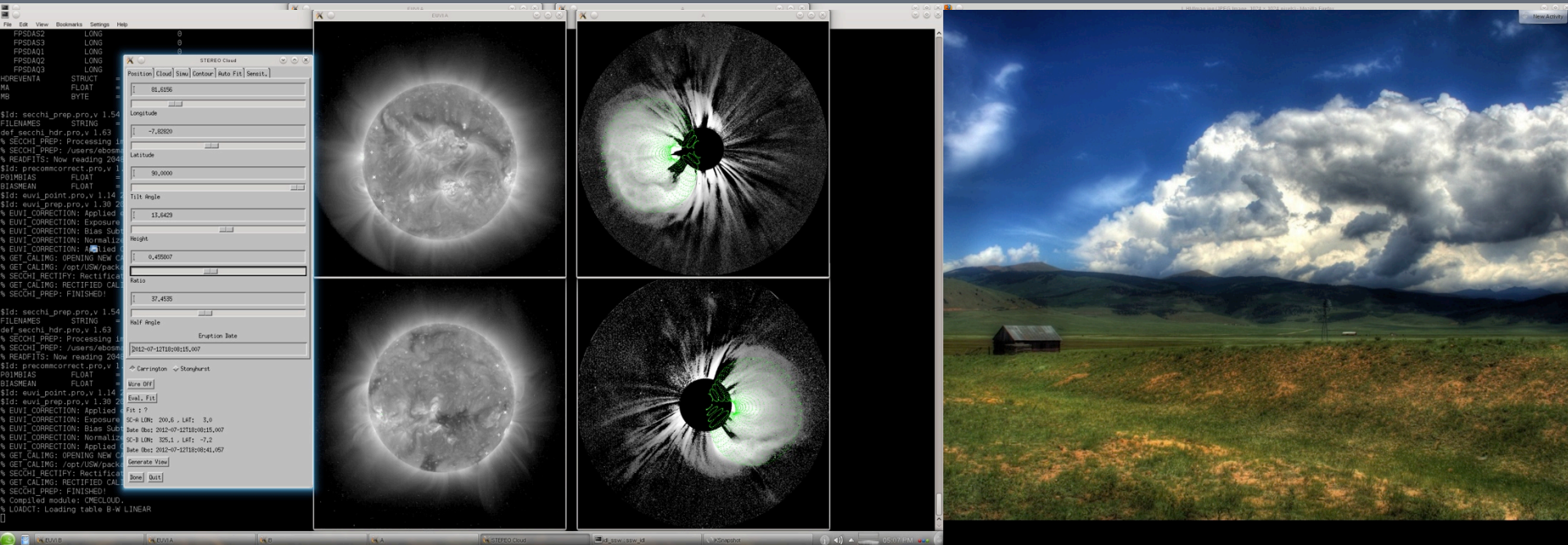
Sample CME 07.06.2011 (sep. angle = 172 deg)

The screenshot displays a software interface for analyzing solar data, specifically a Coronal Mass Ejection (CME) event. The interface is divided into several sections:

- File Explorer (Left):** Shows a directory tree with folders like 'bosman', 'AFFECTS', 'Auswertung', 'CME-Klasse', 'COR2-fits', 'HI1-#418-f', 'HI1-fits', '+Modellier', and '201004'. The 'Ergebnis' folder is selected.
- STEREO Cloud Control Panel (Top Left):** Contains input fields for various parameters:
 - Position [Cloud] Simu | Contour | Auto Fit | Sensit.:
 - Longitude: 79.3800
 - Latitude: -67.6404
 - Tilt Angle: 14.3573
 - Height: 0.551114
 - Ratio: 24.3171
 - Half Angle:
 - Eruption Date: 2010-08-01T10:08:15,008
 - Buttons: 'Wire Off', 'Eval. Fit', 'Generate View', 'Quit'.
 - Fit: ?
 - SC-A LON: 187.2, LAT: 5.4, Date Obs: 2010-08-01T10:08:15,008
 - SC-B LON: 37.5, LAT: -2.5, Date Obs: 2010-08-01T10:09:04,153
 - Buttons: 'Generate View'.
- EUVI A (Top Left View):** Shows a grayscale image of the Sun with a white arrow pointing to a feature. Timestamp: 2010/08/01 08:06:15.
- A (Top Right View):** Shows a 3D reconstruction of the CME structure in green, centered on the Sun. The structure is elongated and fan-shaped.
- EUVI B (Bottom Left View):** Shows a grayscale image of the Sun with a green arrow pointing to a feature. Timestamp: 2010/08/01 08:07:04.
- B (Bottom Right View):** Shows a 3D reconstruction of the CME structure in green, viewed from a different angle than view A.

The bottom of the interface shows a taskbar with several open applications, including 'bothmer...', 'Ergebnis ...', 'Posteing...', and 'Seiten-L...'. The system tray shows the date 'Do, 16. Jun, 10:47' and the user name 'Bothmer'.

Distorted wave fronts similar to clouds





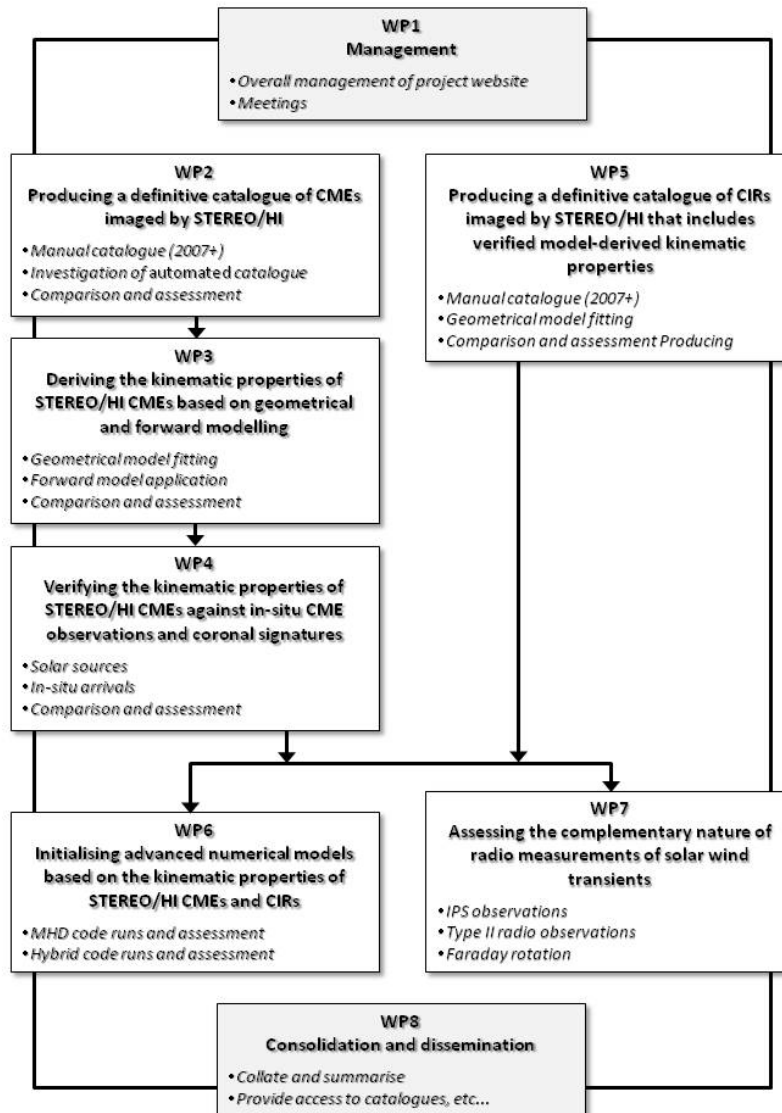
Task 3.4 - Comparison of modelling results (Task leaders: RAL, UGOE; Additional participant: TCD)

- Inter-comparison of the results of the geometrical, forward and inverse modelling of STEREO/HI observations (Tasks 3.1, 3.2 and 3.3, respectively), as well as comparing with the COR2 model results





Workflow Diagram



- CME catalogue from WP2 as baseline
- Inclusion of CME modelling results into CME catalogue, including update until end of 2011
- Intercomparison of modelling results
- Provision of derived results to WP4 task 4.1 (coronal sources)





WP 3 - Deliverables

- D3.1: Provision of time-elongation (j) maps for the CMEs in the STEREO/HI catalogue (from WP2), and incorporation of the results of the geometrical fitting into the catalogue (first release in PM12, updates to follow, type: O, lead: STFC)
- D3.2: Incorporation of the results of the forward-modelling techniques into the CME catalogue established in WP2 (PM 12, updates to follow, type: O, lead: UGOE)
- D3.3: Report on modelling results (PM 36, type: R, lead: RAL)
- D3.4: Report on prototype inverse model based on photospheric and low coronal source region characteristics for 3-D HI CME structure (PM 36, type: R, lead: UGOE)





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