HELCATS

WP 3

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

Overview

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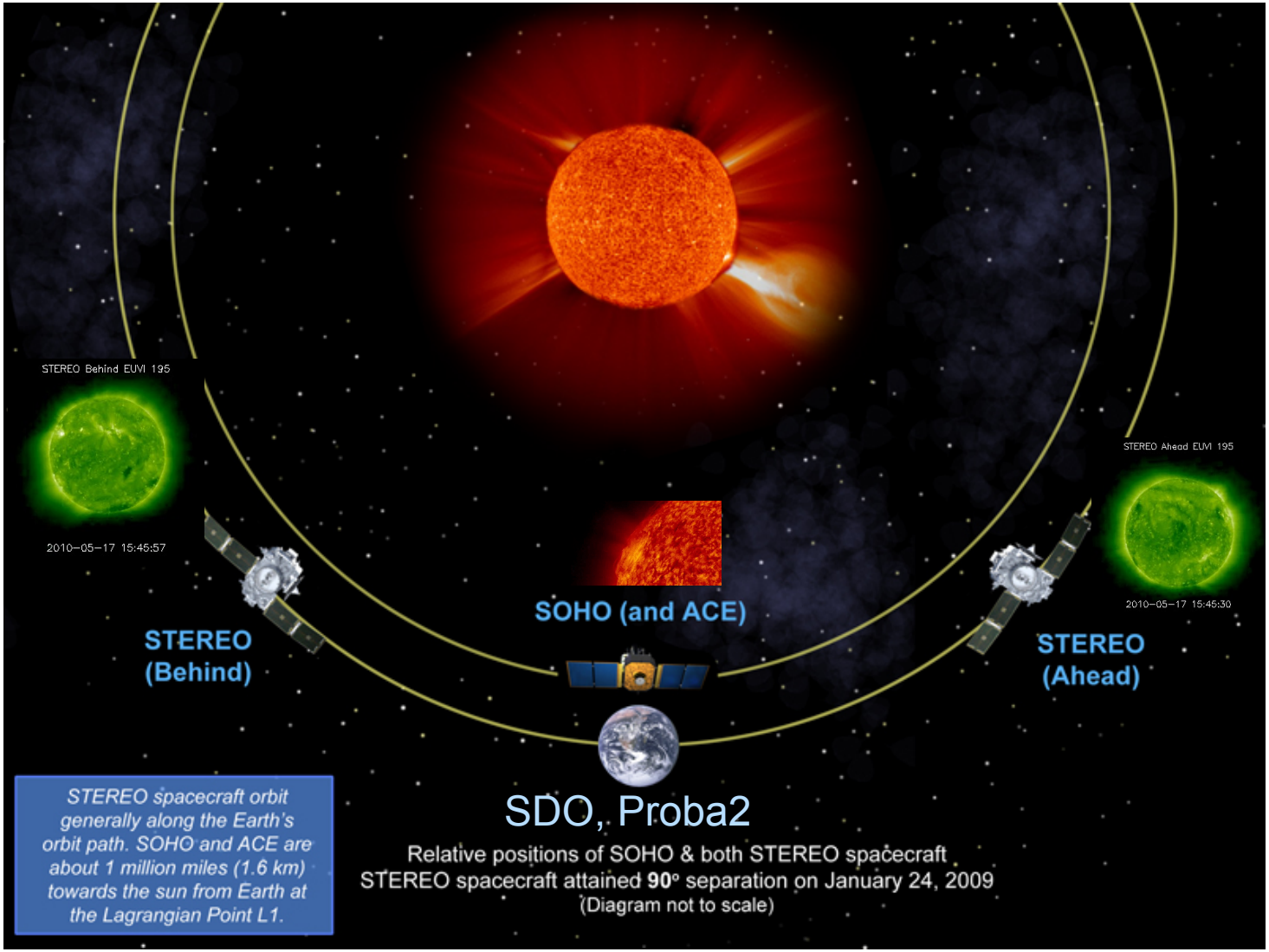
HELCATS Kick-Off Meeting, 14-15 May 2014, RAL, Didcot, UK

WP 3 - Objectives

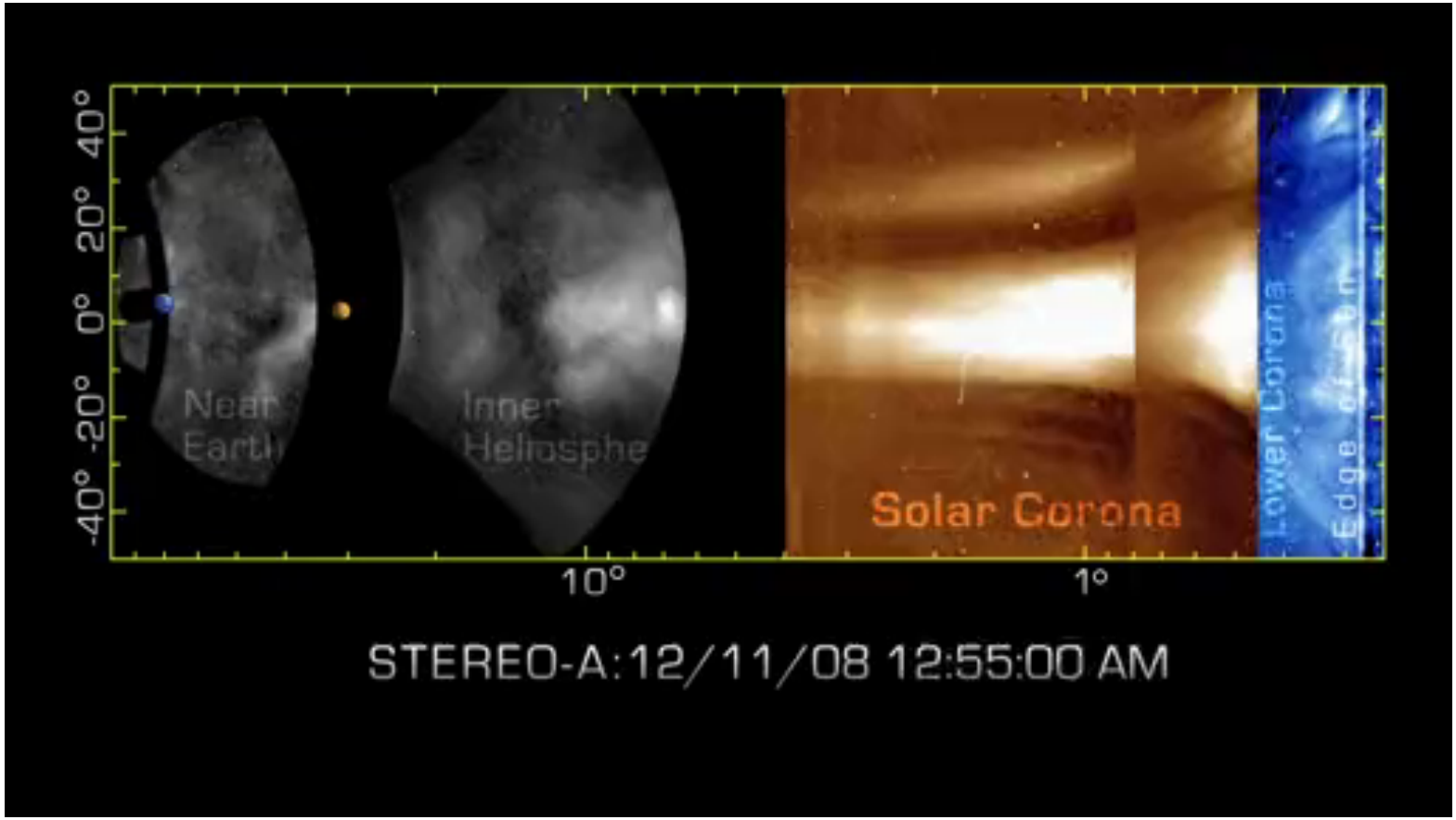
- To obtain the kinematic properties for the STEREO/HI CMEs in the catalogue established in WP2, through application of geometrical and forward-modelling techniques to the HI data
- To augment the STEREO/HI CME catalogue with the model results, and supply those results as input for comparisons with coronal 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



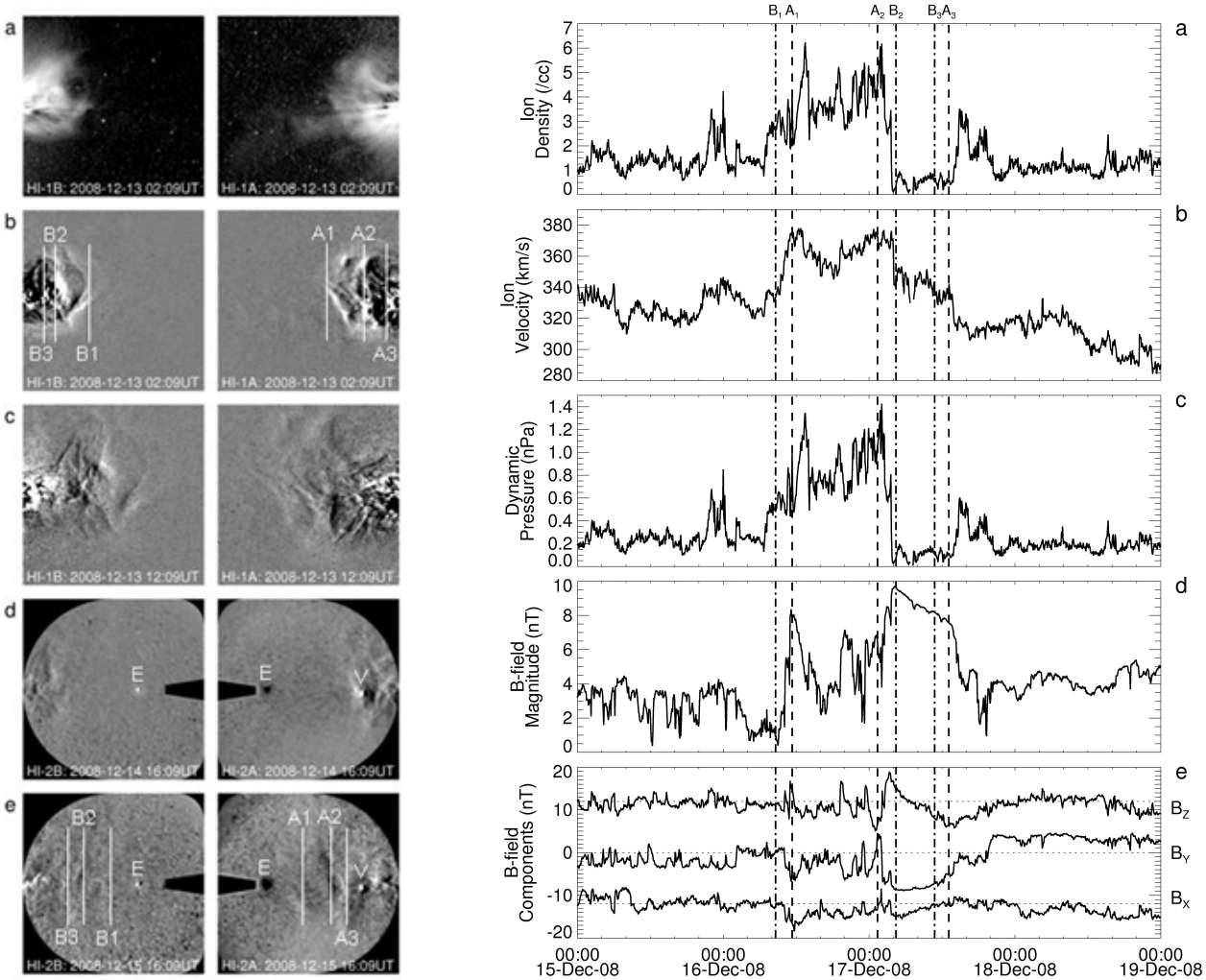
Credits: NASA/STEREO/SECCHI

CME – Sun to Earth Tracking



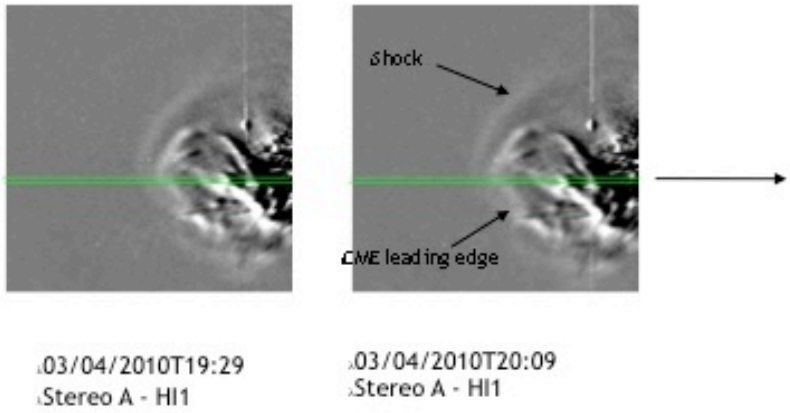
Credits: NASA/STEREO/SECCHI

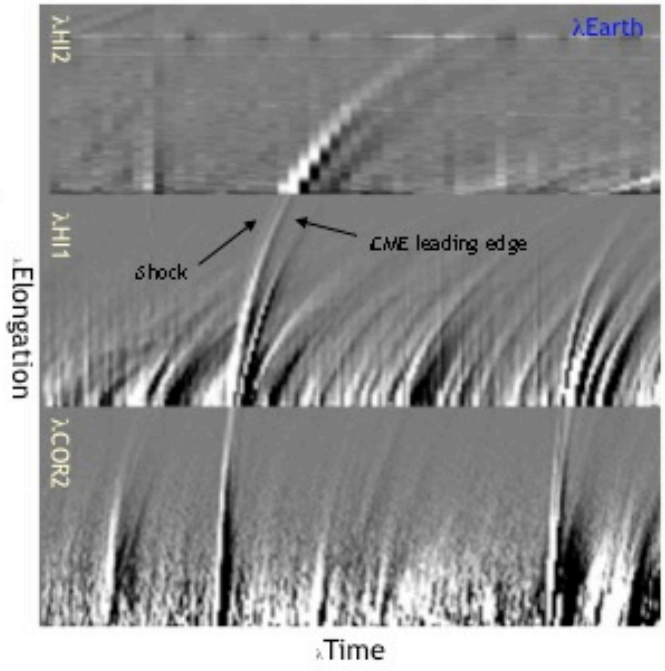
CME – HI Tracking and In-Situ Measurements

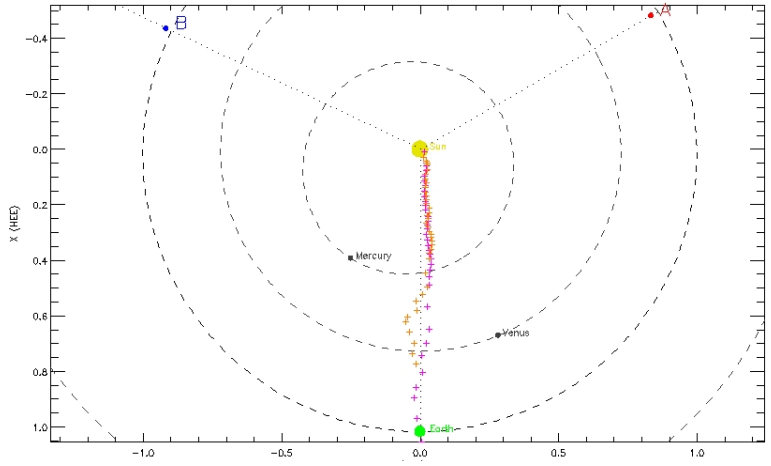


Davis et al., 2009

Time-elongation (J) maps



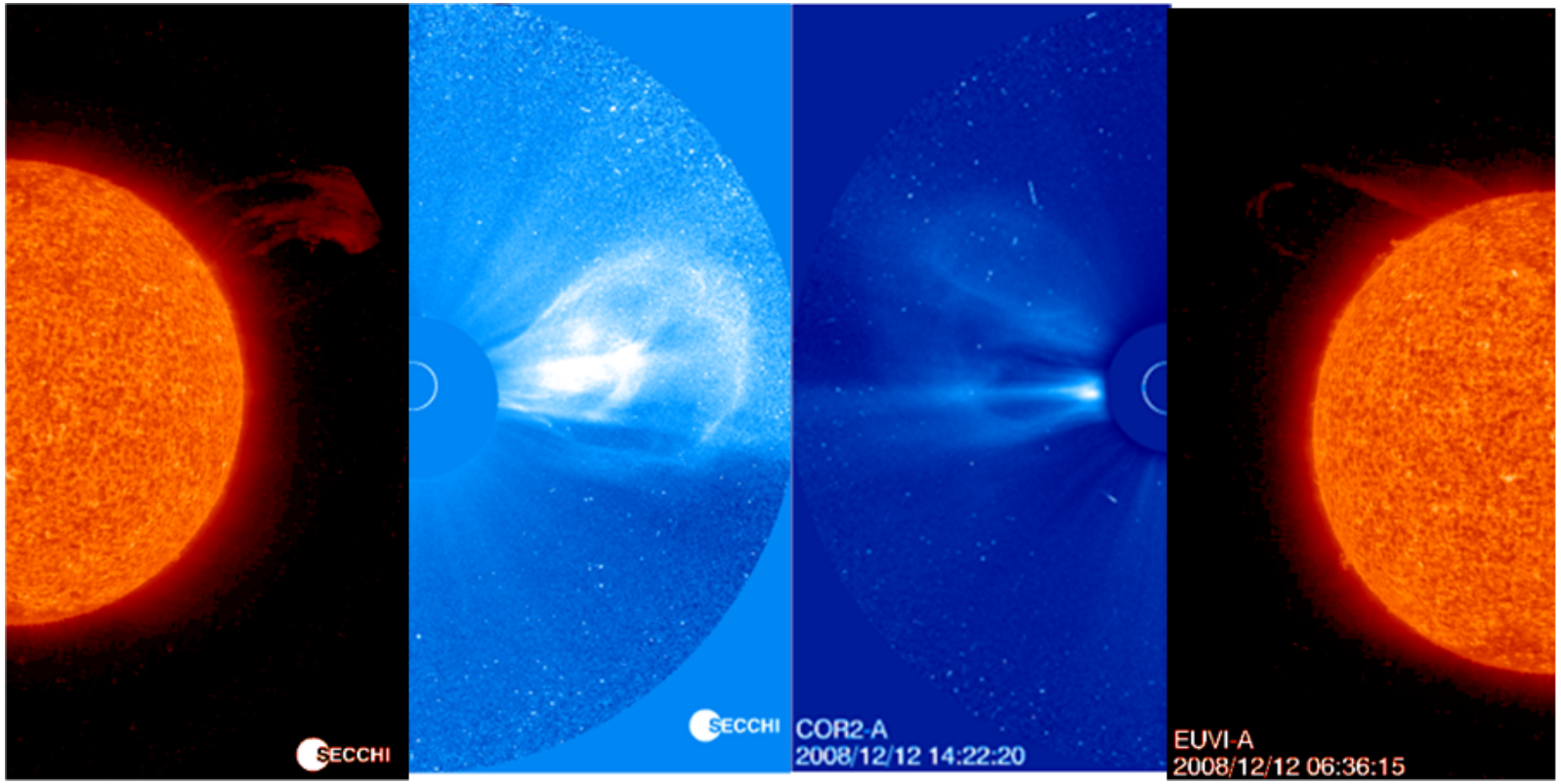




J-map technique;
Courtesy: L. Volpes

Courtesy: L. Volpes, J. Davies

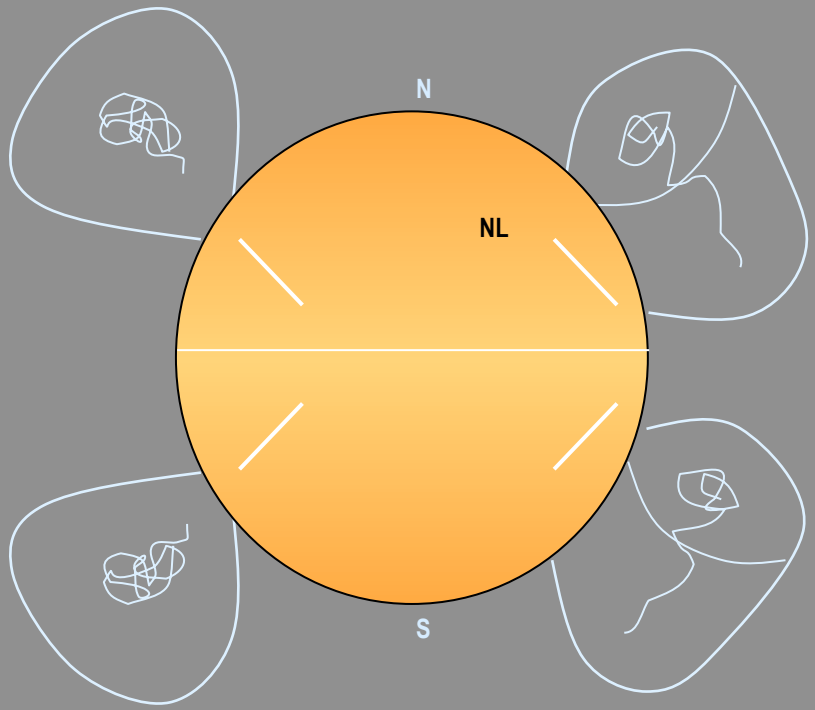
STEREO SECCHI/EUVI A, B 304 Å and COR 2 A, B Observations



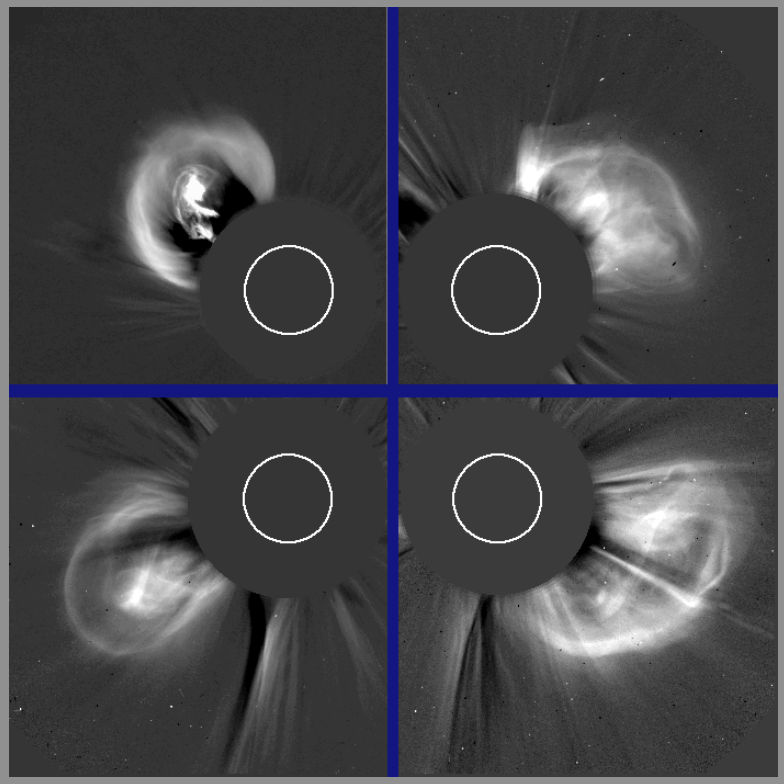
Basic Scheme Explaining the 3D Structure of CMEs

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



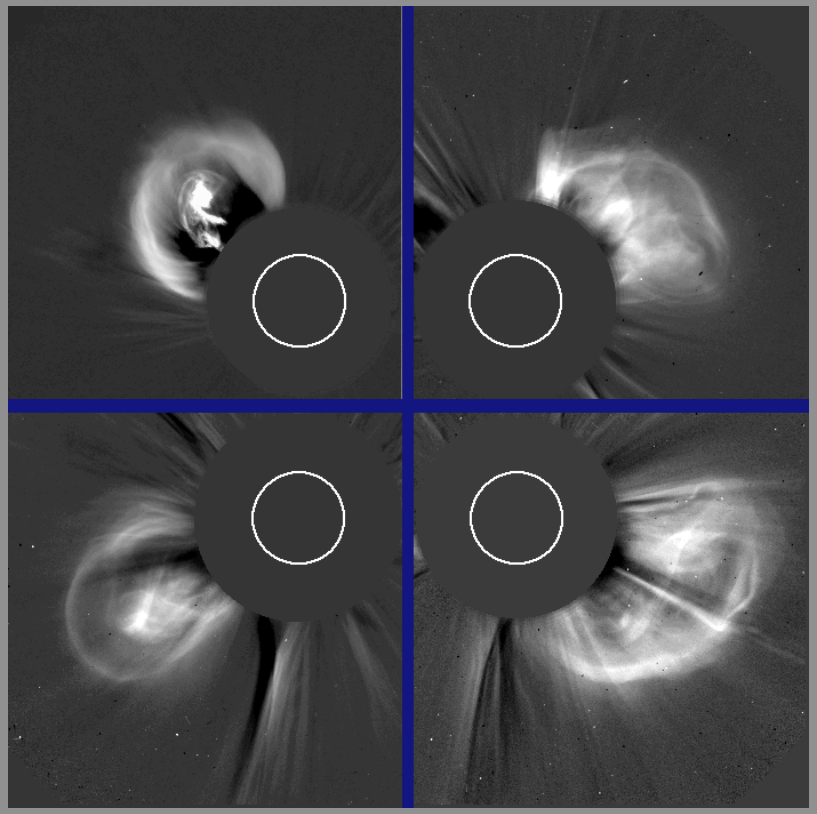
Cremades & Bothmer, A&A 2004



SOHO/LASCO C2

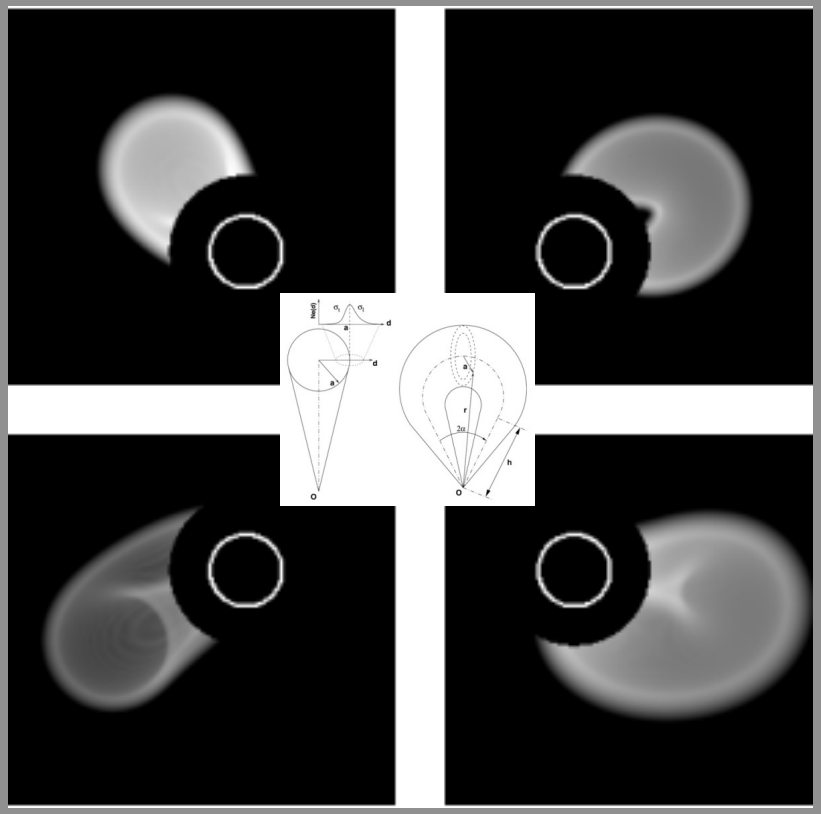
Modelling the Electron Density Distribution

LASCO Observations



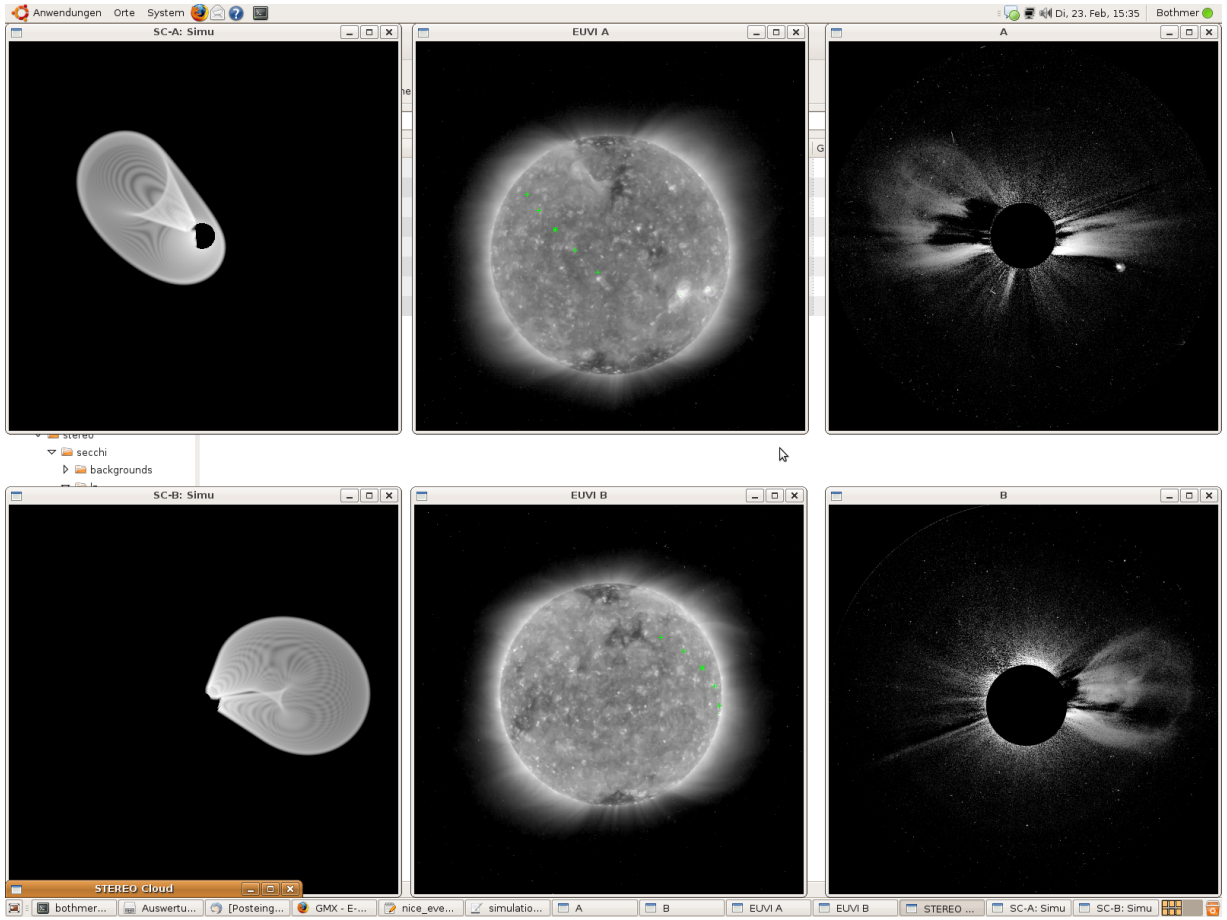
Cremades & Bothmer, A&A 2004

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



Howard, Thernissien and Vourlidas, ApJ 2006

CME GCS Forward Modelling



SR:

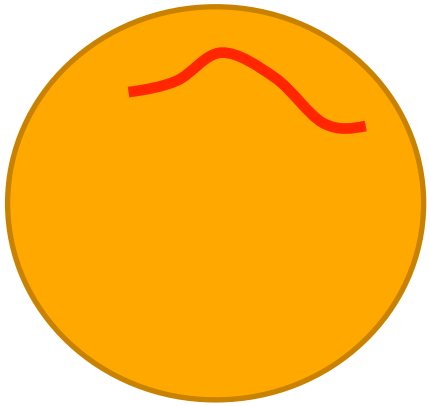
CLON = 81°

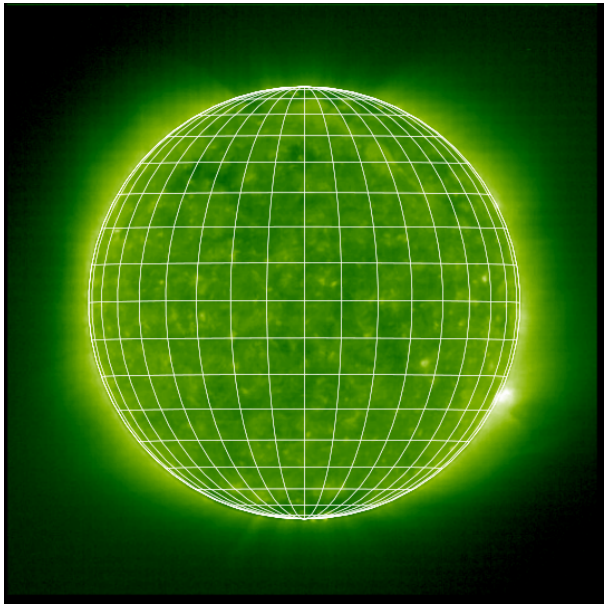
CLAT = N10

θ = +42°

Courtesy: E. Bosman

Low Coronal Signatures

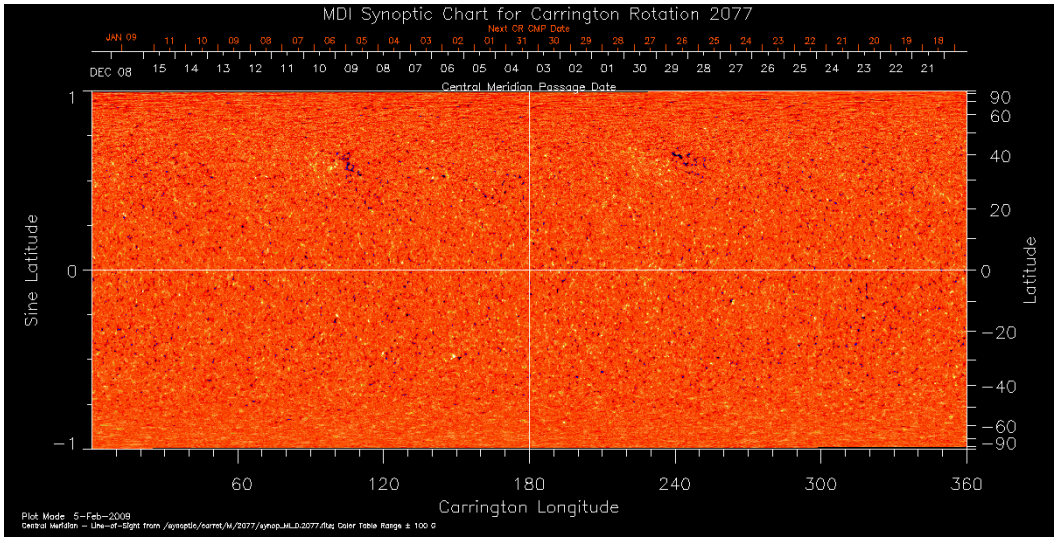


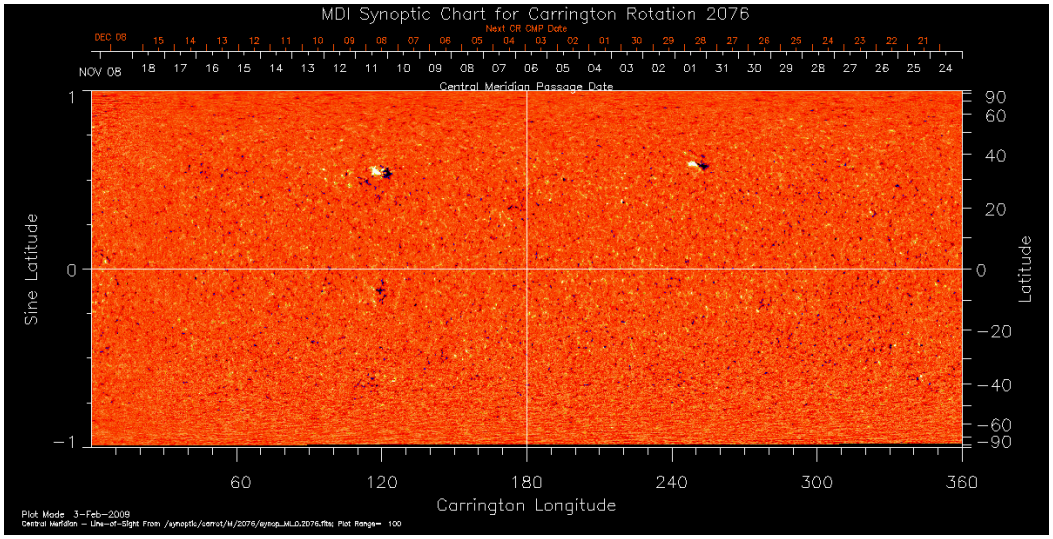


Estimated onset time:
December 12, 08 UT

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.

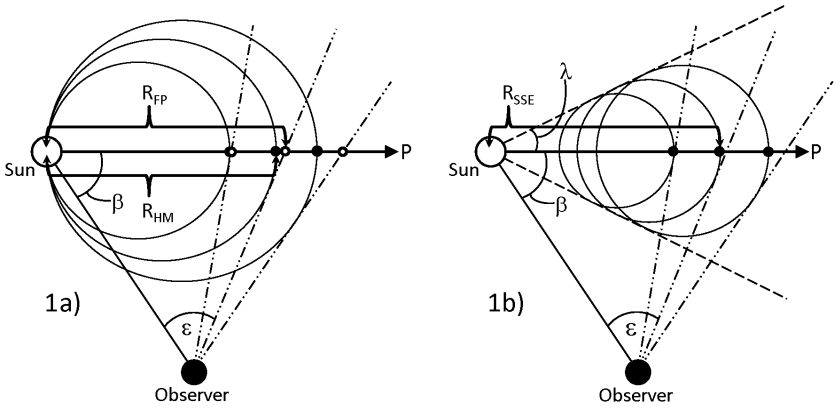
- **Task 3.3: Inverse modelling of STEREO/HI CMEs (Task leader: UGOE; Additional participant: TCD)**
  Instruments used: STEREO/SECCHI/HI, COR2
  Role of participants: UGOE: modelling; TCD: source region input expertise.

- **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

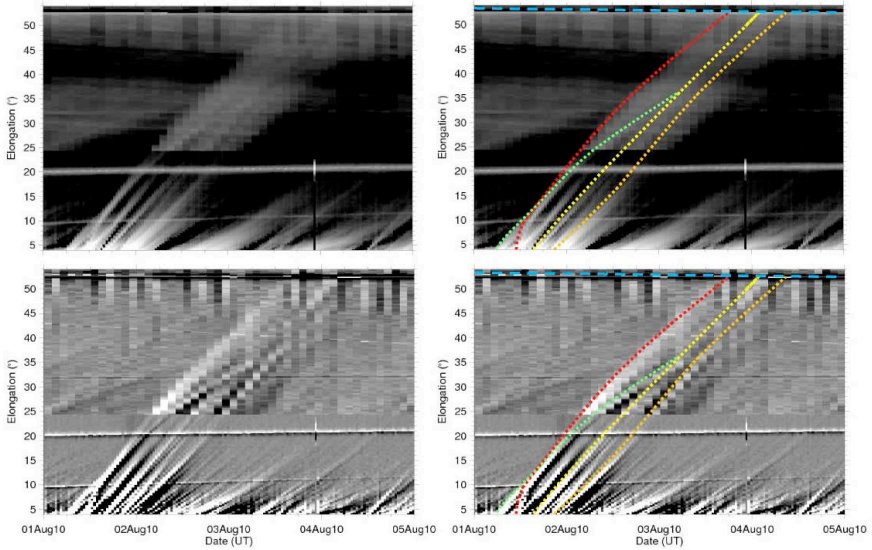
- Geometrical modelling of the STEREO/HI CMEs identified and catalogued in WP2
- Creation of J-maps for backward (to source regions) and forward extrapolations (for solar system applications)
- Derivation of CME kinematic properties (propagation speed, direction and potentially size, launch time, source 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.

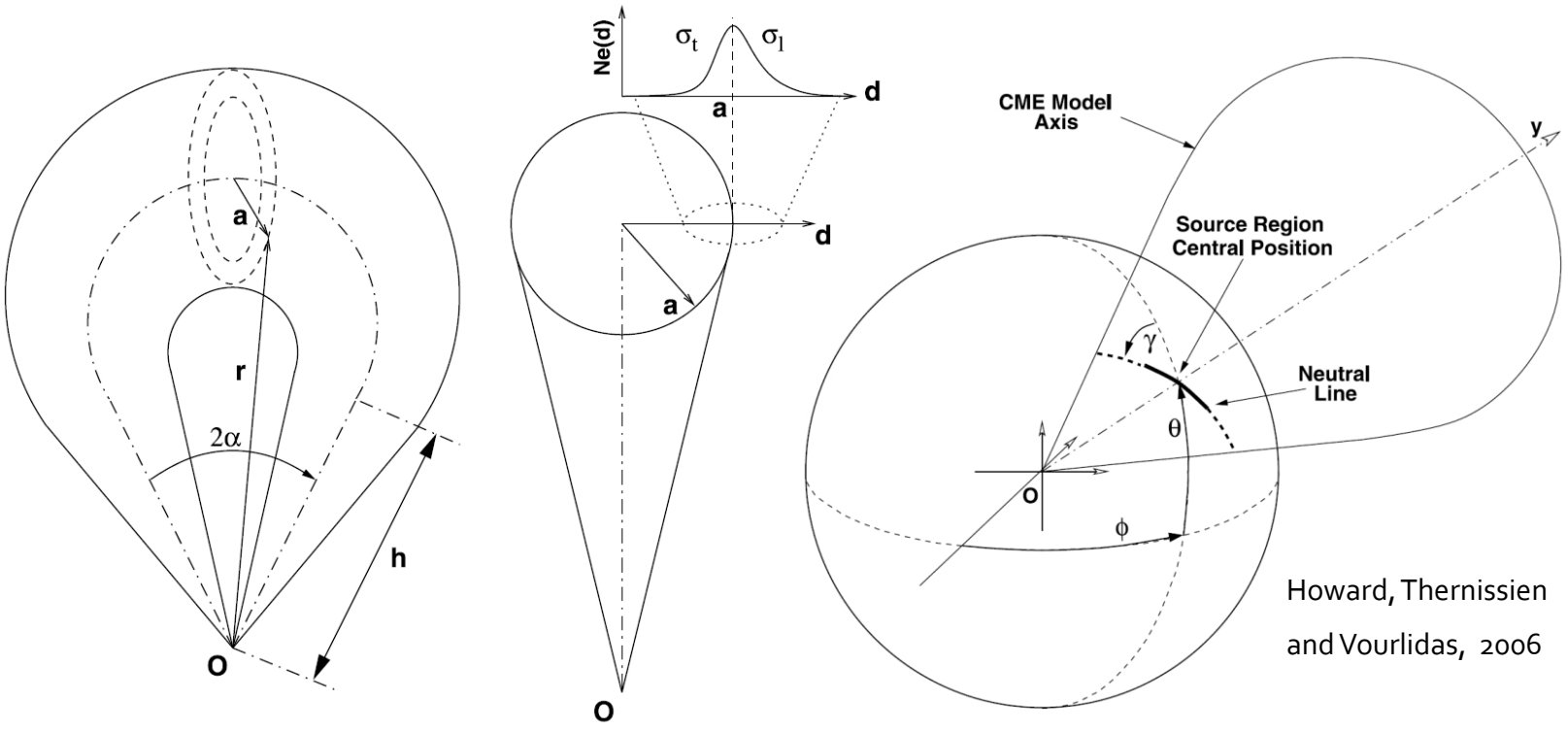
Time-elongation maps (J-maps; see Davies et al. 2009) showing a sequence of CMEs launched on 1st August 2010. Observations taken in the ecliptic plane are presented. Upper frames show background-subtracted data; lower frames use an image difference technique.
Right-hand frames are overlaid with the CME 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		
κ = 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

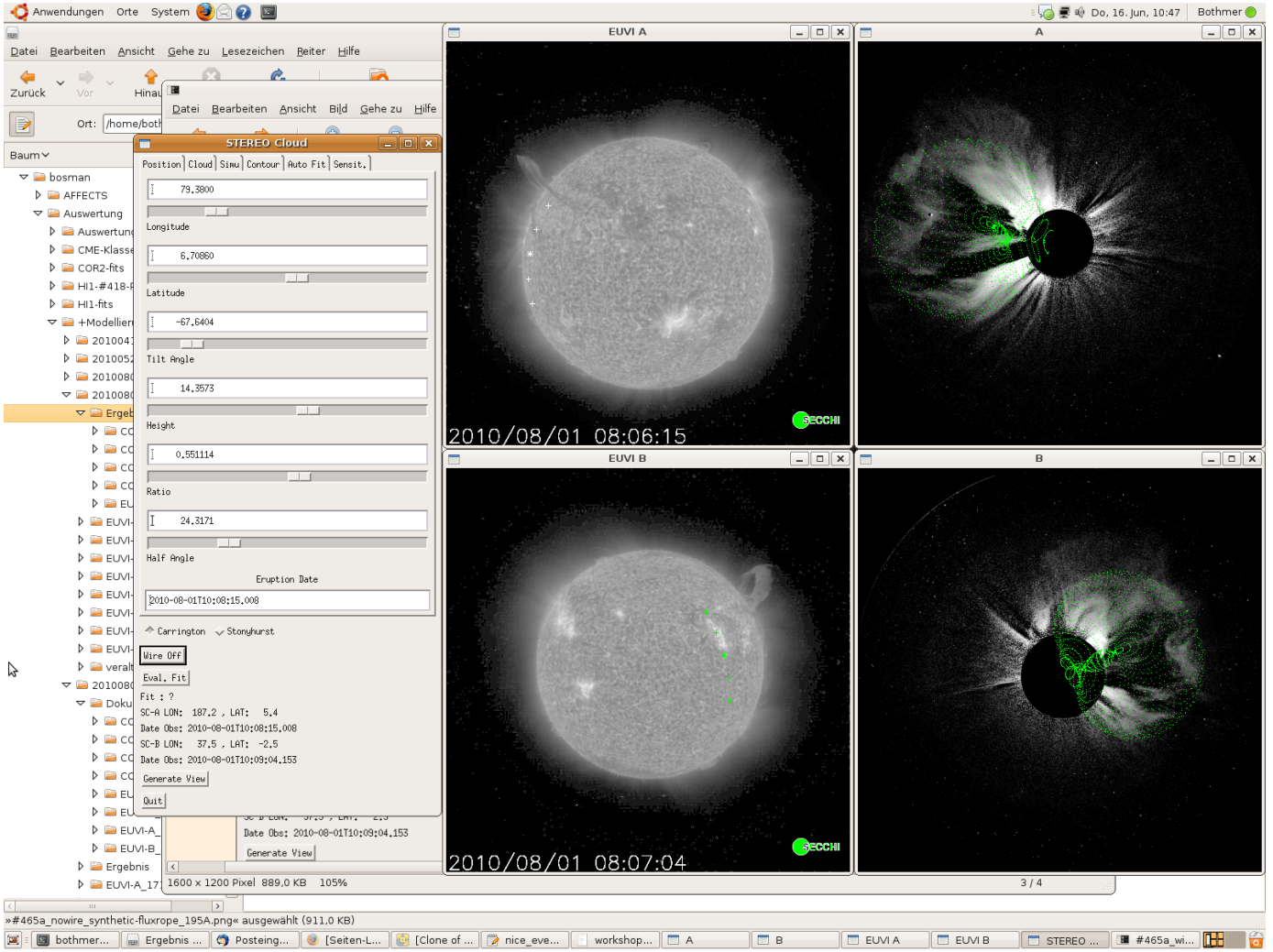
CME-Modeling

- 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)

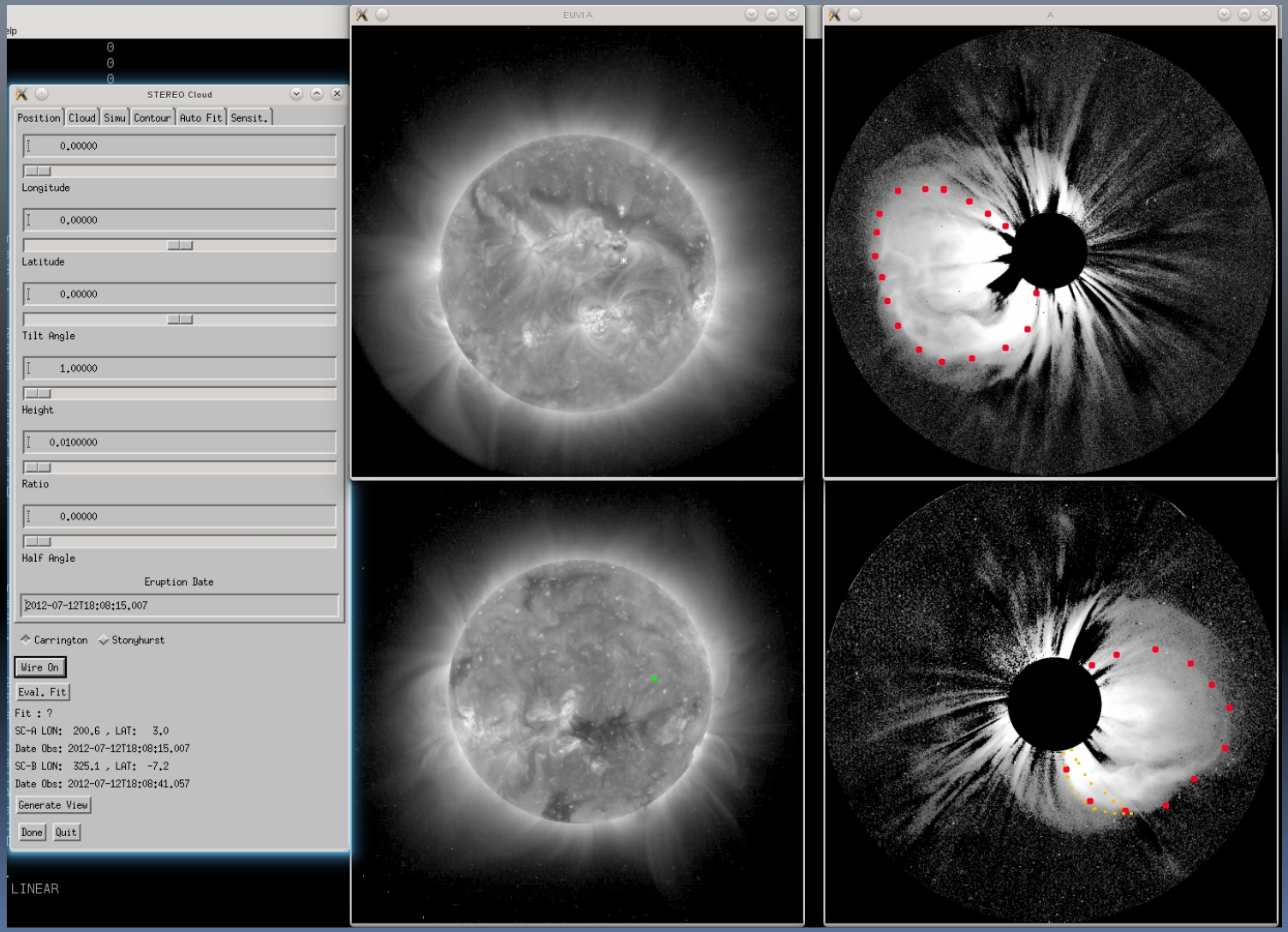
- Prototype the use of inverse modelling to derive typical parameters (speed, size and mass) for the CMEs in the CME catalogue (speed, size and mass) for photospheric and low coronal source regions

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



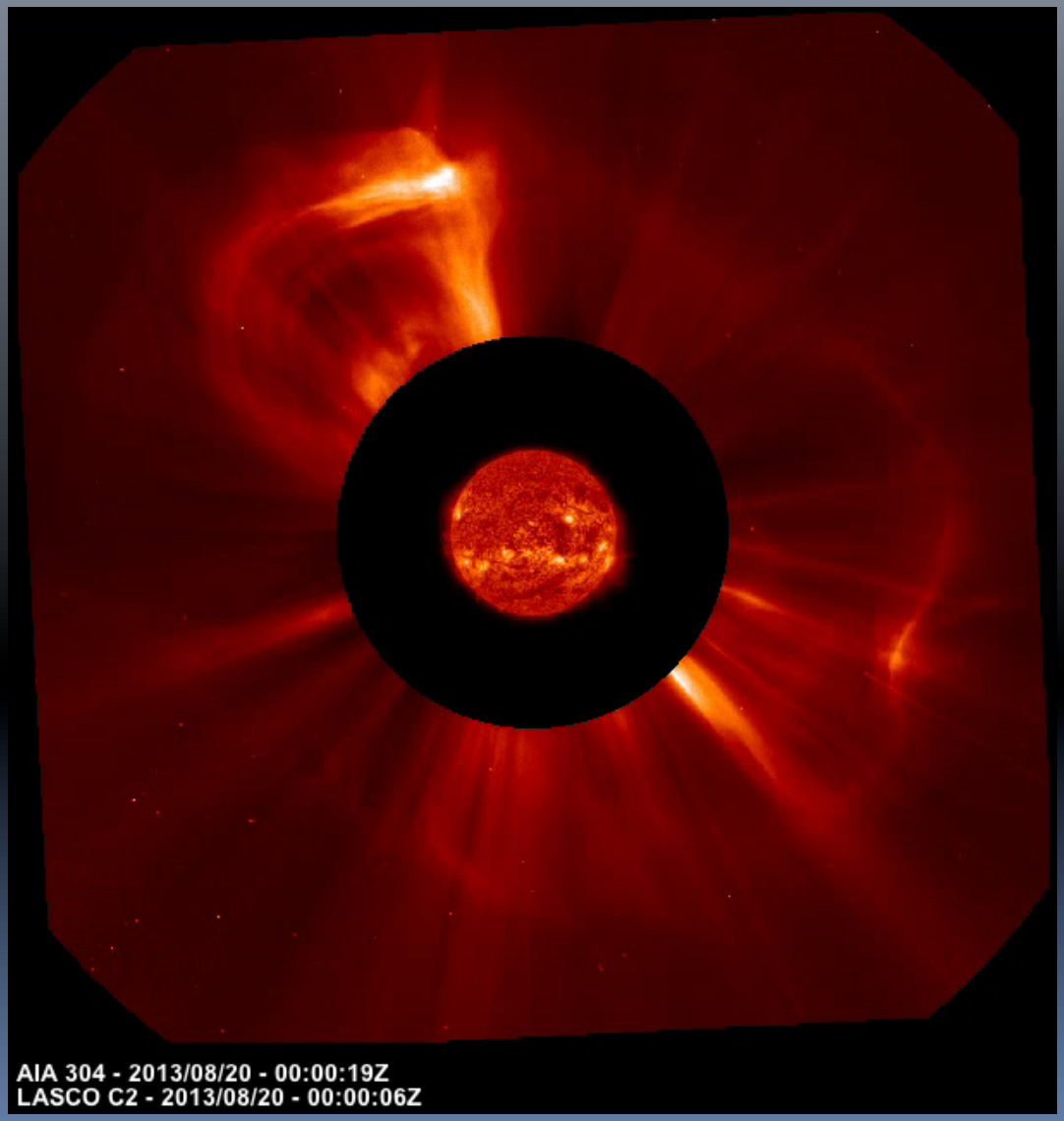
FR Modeling Complications

Shock fronts ahead of CMEs

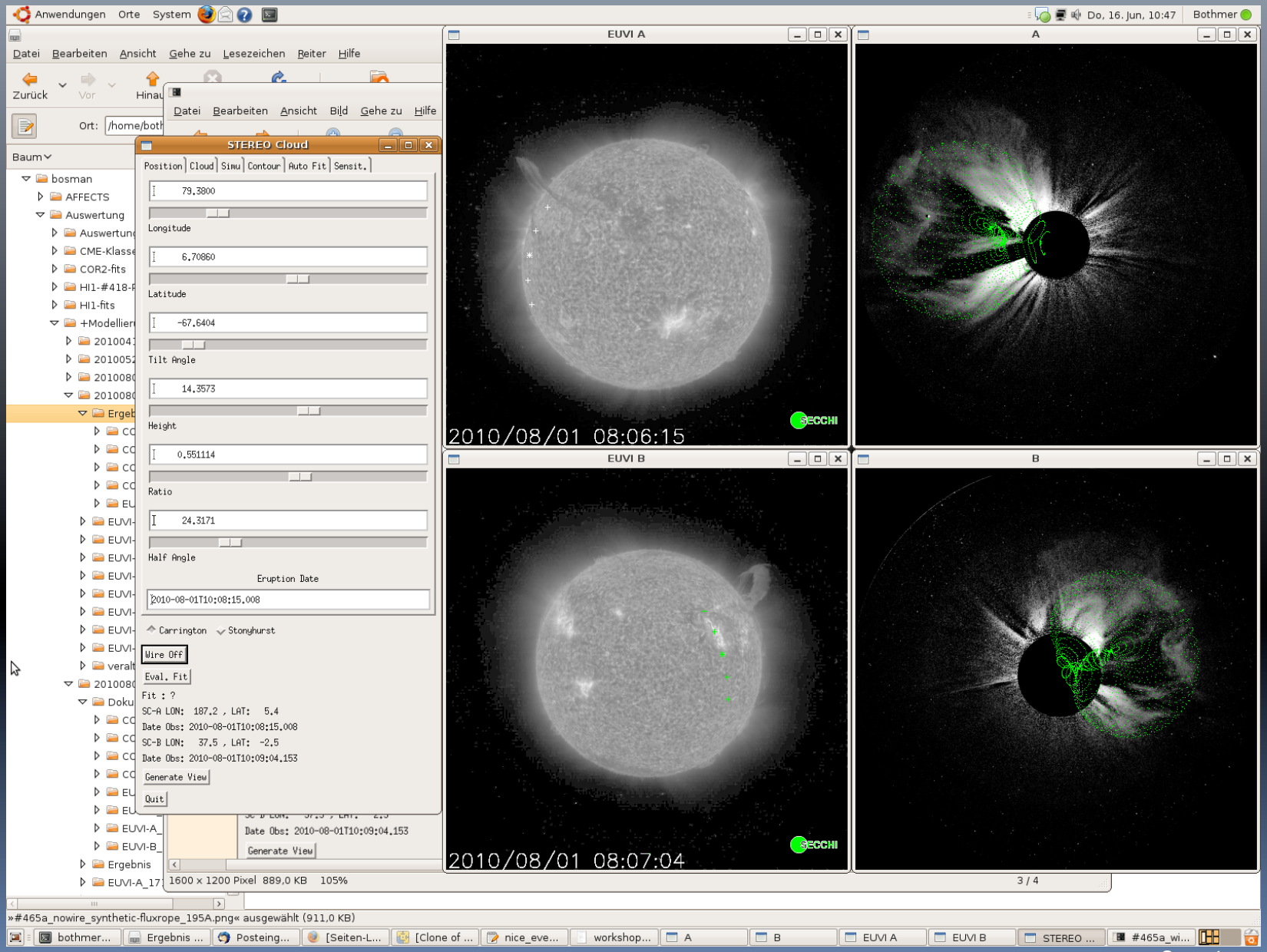


Courtesy: E. Bosman

Distorted CME front – SOHO/LASCO



Sample CME 07.06.2011 (sep. angle = 172 deg)



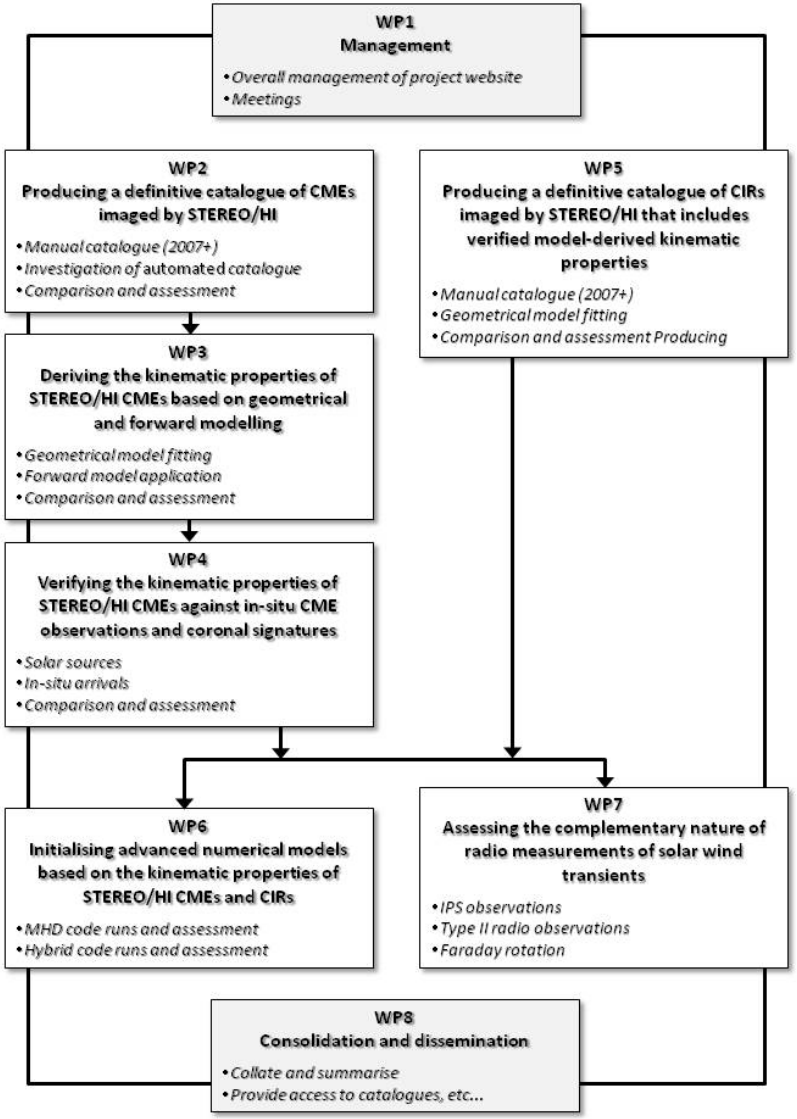
Courtesy: E. Bosman

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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