HELCATS

WP 3

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

WP3 update – overview and forward modelling

Volker Bothmer & WP3 Team

HELCATS AM, 5-6 November 2014, ROB, Brussels, Belgium

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/SECCHI/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

WP 3 – Task Summary (PMs: 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.

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 M12, 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 (M 12, updates to follow, type: O, lead: UGOE)
- D3.3: Report on modelling results (M 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 (M 36, type: R, lead: UGOE)

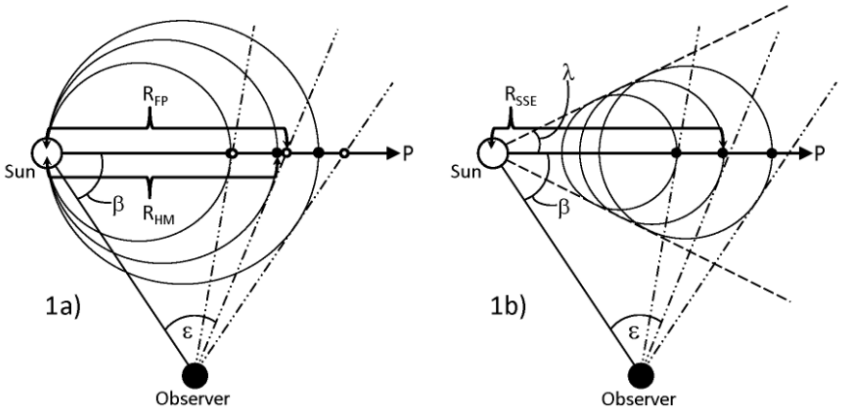
Update Task 3.1 - Geometrical modelling of STEREO/HI CMEs
Task leader: STFC; Additional participant: UNIGRAZ

- 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)

Deliverable in PY 1

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 M12, updates to follow, type: O, lead: STFC)

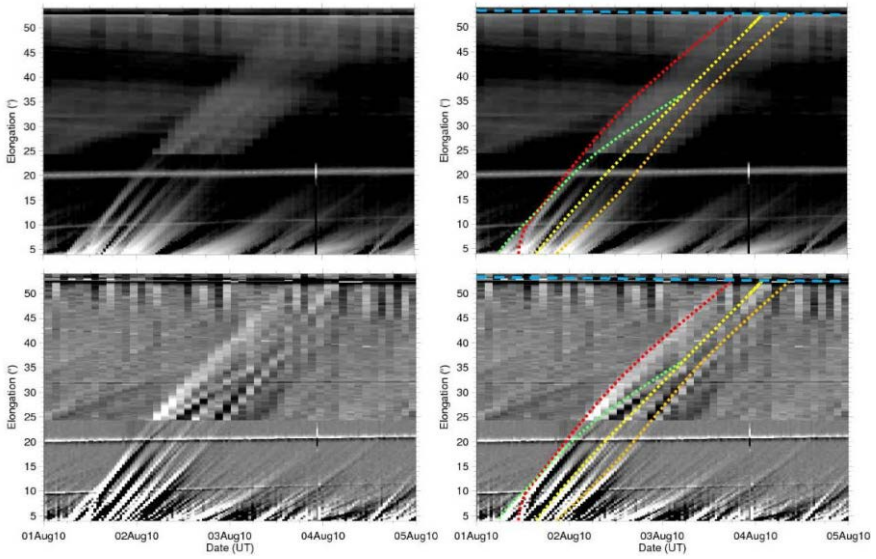
Geometrical modelling of STEREO/HI CMEs



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.

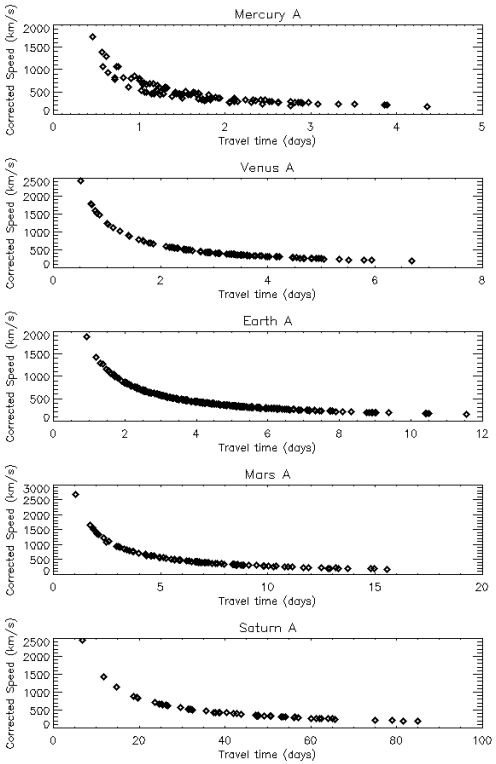
Time-elongation maps (J-maps; see Davies et al. 2009) showing a sequence of CMEs launched on 1st August 2010. Observations taken in the ecliptic plane are presented. Upper frames show background-subtracted data; lower frames use an image difference technique.

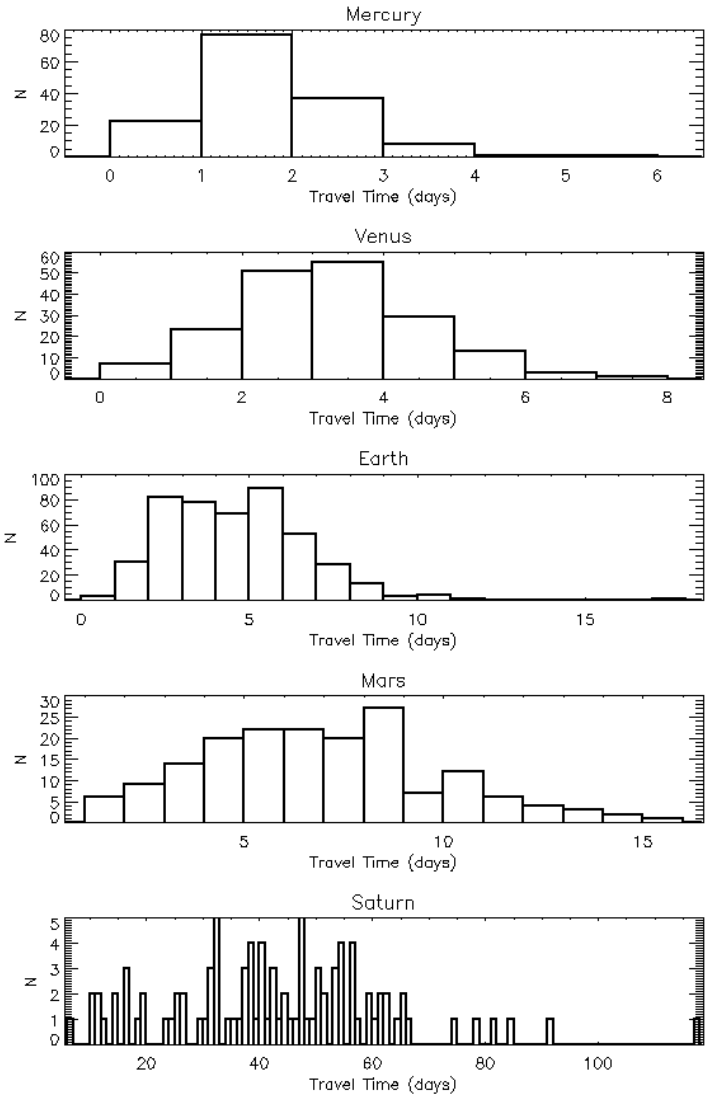
Right-hand frames are overlaid with the CME tracks that were used to extract kinematic properties using FP and HM models (from Harrison et al. 2012).



Predicting Arrival Times

- UNIGRAZ has completed initial code testing for arrival time predictions of geometrically modelled CMEs at Mercury, Venus, Earth, Mars and Saturn based on SSEF corrected speed method (Möstl & Davies, 2012).





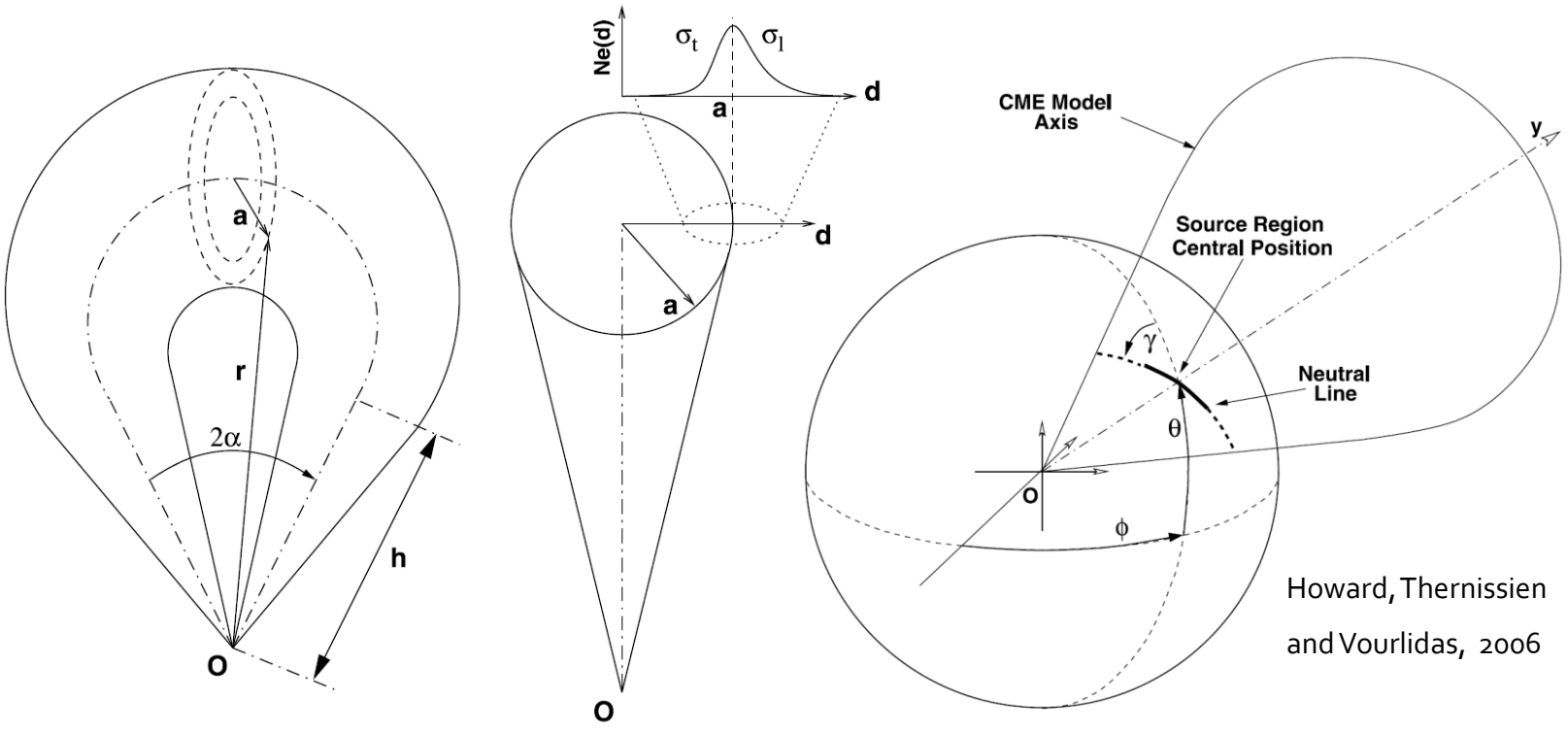
Update Task 3.2 - Forward modelling of STEREO/HI CMEs (Task leader: UGOE)

- 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

Deliverable in PY 1

- D3.2: Incorporation of the results of the forward-modelling techniques into the CME catalogue established in WP2 (M 12, updates to follow, type: O, lead: UGOE)

Geometry of Graduated Cylindrical Shell (GCS) Model

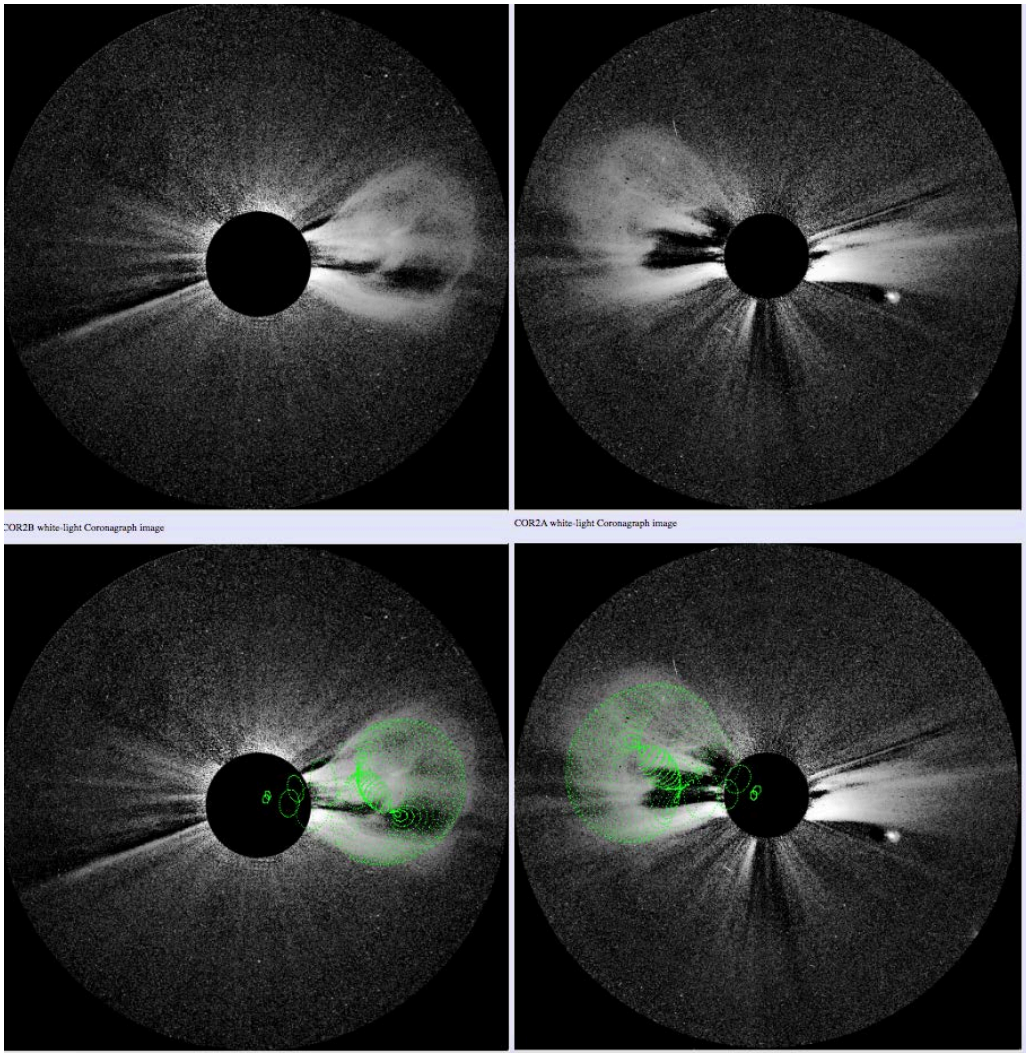


Howard, Thernissien and Vourlidas, 2006

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

Sample STEREO/SECCHI/COR2 CME GCS Forward Modelling – December 12, 2008, 14:22 UT



The Fitting with the GCS Forward-Modeling Code yields the following results.

GCS Fit-Parameter from Modeling:
Carrington Longitude: **70.434**
Carrington Latitude: **5.031**
Tilt Angle: **50.870**
Height: **16.071**
Ratio: **0.268**
Half Angle: **10.061**

Timestamp of used COR2-Images for Modeling: **20081212 14:22:00**
#formatting: yyyymmdd hhmmss

Courtesy: E. Bosman

Development of COR2 CME list

Selection Criteria

- Based on clarity of CME appearance in STEREO/SECCHI/COR2 FOV (2.5 – 15 R_s)

Best-Of CMEs

- List with 1071 events until end of 2011 established

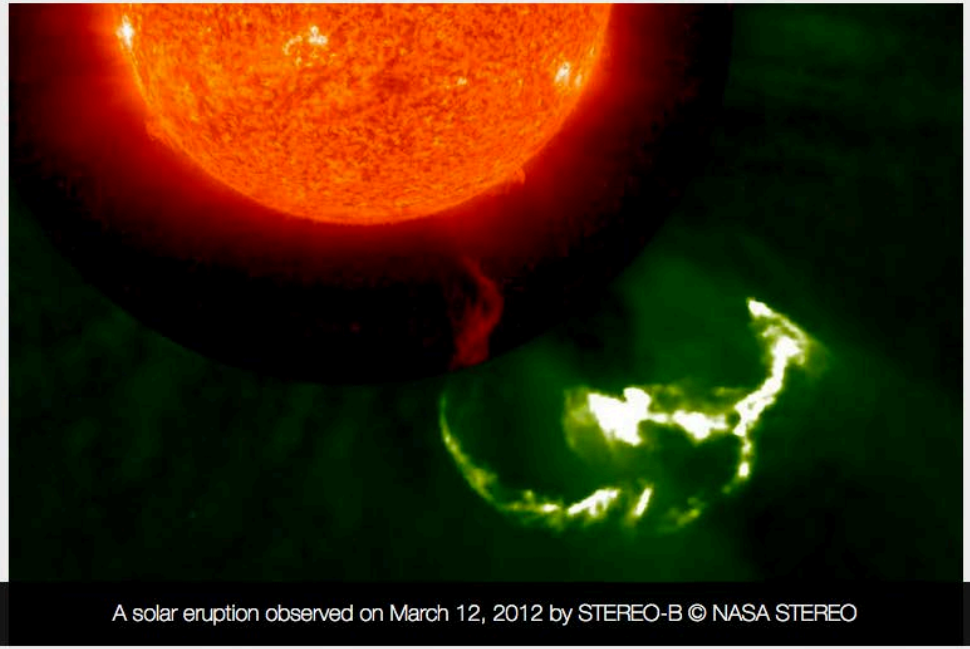
CME-Modeling

- 263 “best-of CMEs” studied by GCS modelling (Thernisien, Howard, Vourlidas, 2006) based on 3-D concept for CMEs (derived by Cremades & Bothmer , 2004)

All results are available online @ www.affects-fp7.eu/cme-database/

COR2 CME list

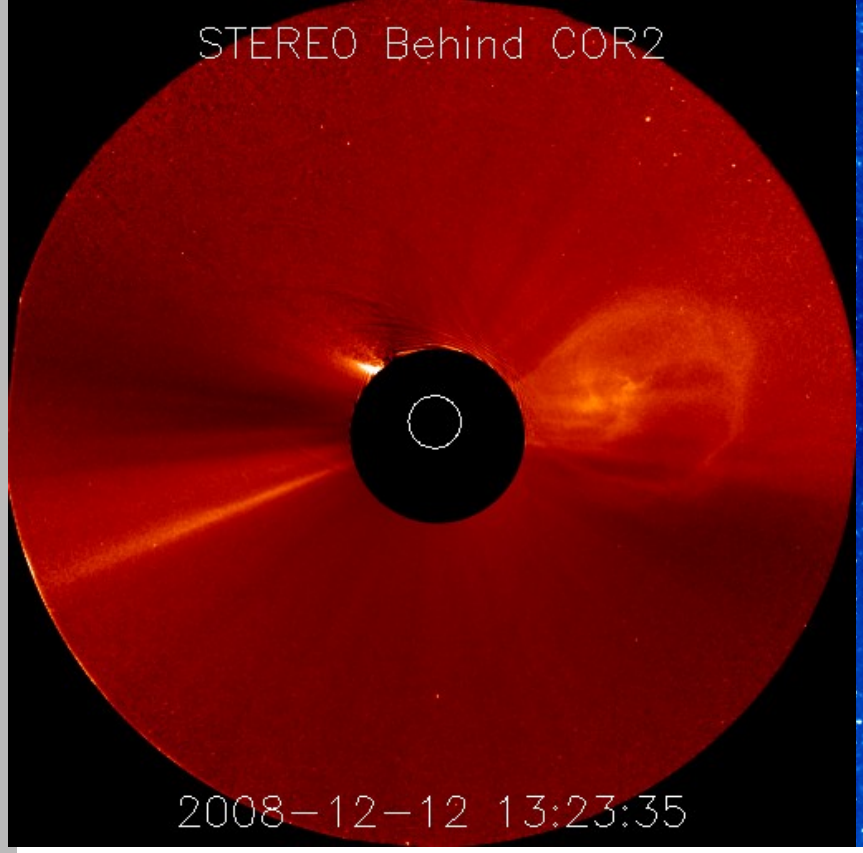
Institute for Astrophysics Göttingen | Home | Background | Database | People | Credits | Links | Contact

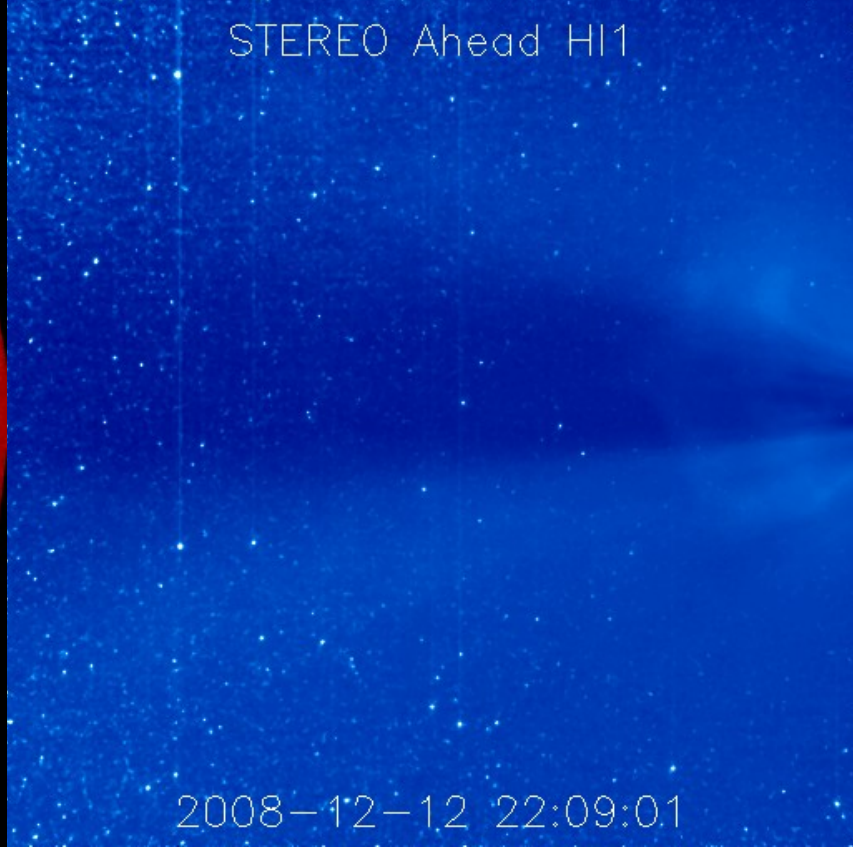


A solar eruption observed on March 12, 2012 by STEREO-B © NASA STEREO

Coronal Mass Ejection Database

Welcome to the STEREO/SECCHI/COR2 CME-Database of the Institute for Astrophysics, University of Goettingen, Germany. This site provides currently information on identified CMEs in the SECCHI/COR2 synoptic movies available at the NRL SECCHI website in the SECCHI/COR2 field of view at distances between 2 - 15 solar radii. Since launch of the STEREO mission in October 2006, 1071 bright above the coronal background appearing CMEs were identified from January 2007 until end of December 2011. For these events the database contains information about basic CME properties comparable to the SOHO/LASCO CME catalog and spacecraft positions. Out of a selected set of 264 CMEs, which appeared very clear in brightness and structure, 241 ot them were analyzed with the Graduated Cylindrical Shell (GCS) modeling technique developed by Thernisien, Vourlidas and Howard in 2006 based on the 3D CME scheme introduced by Cremades and Bothmer in 2004.





UGOE

COR2 list 2007-2011
STEREO A&B

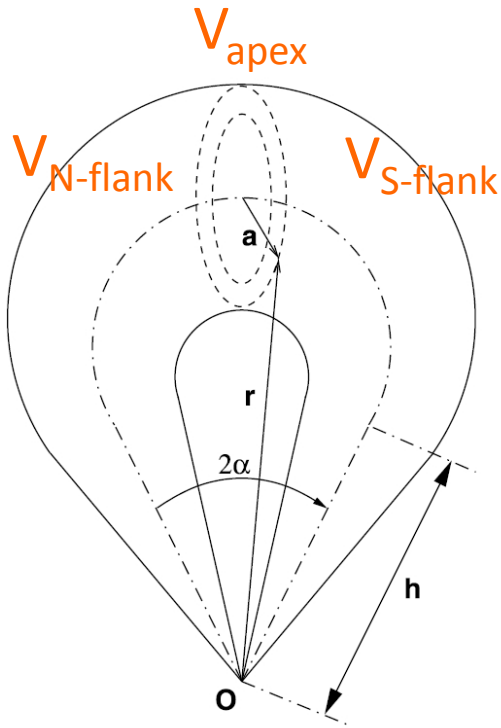
90 CMEs

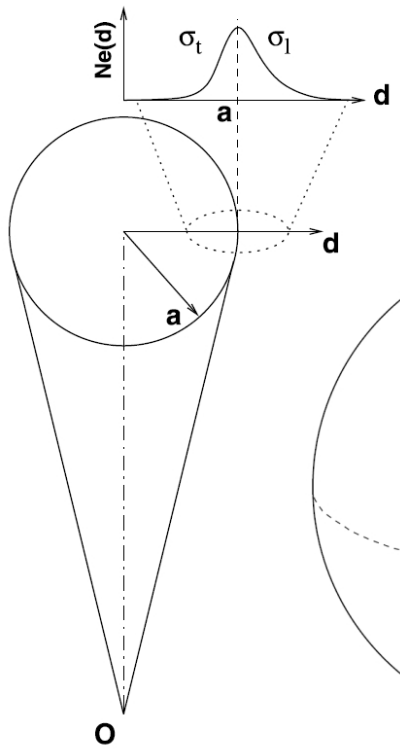
HELCATS

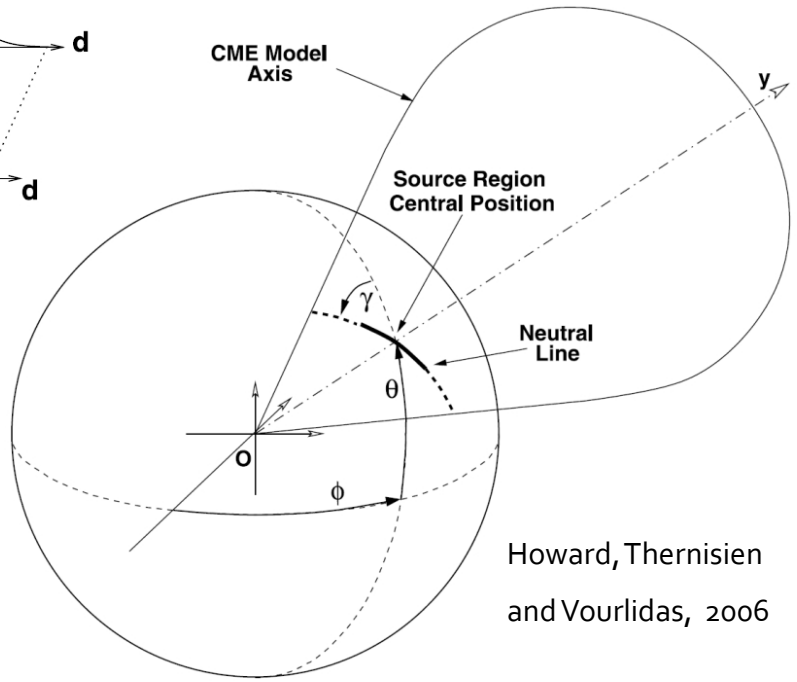
RAL

HI list 2007-2013
STEREO A&B

Speed determination with GCS parameters







Howard, Thernisien and Vourlidas, 2006

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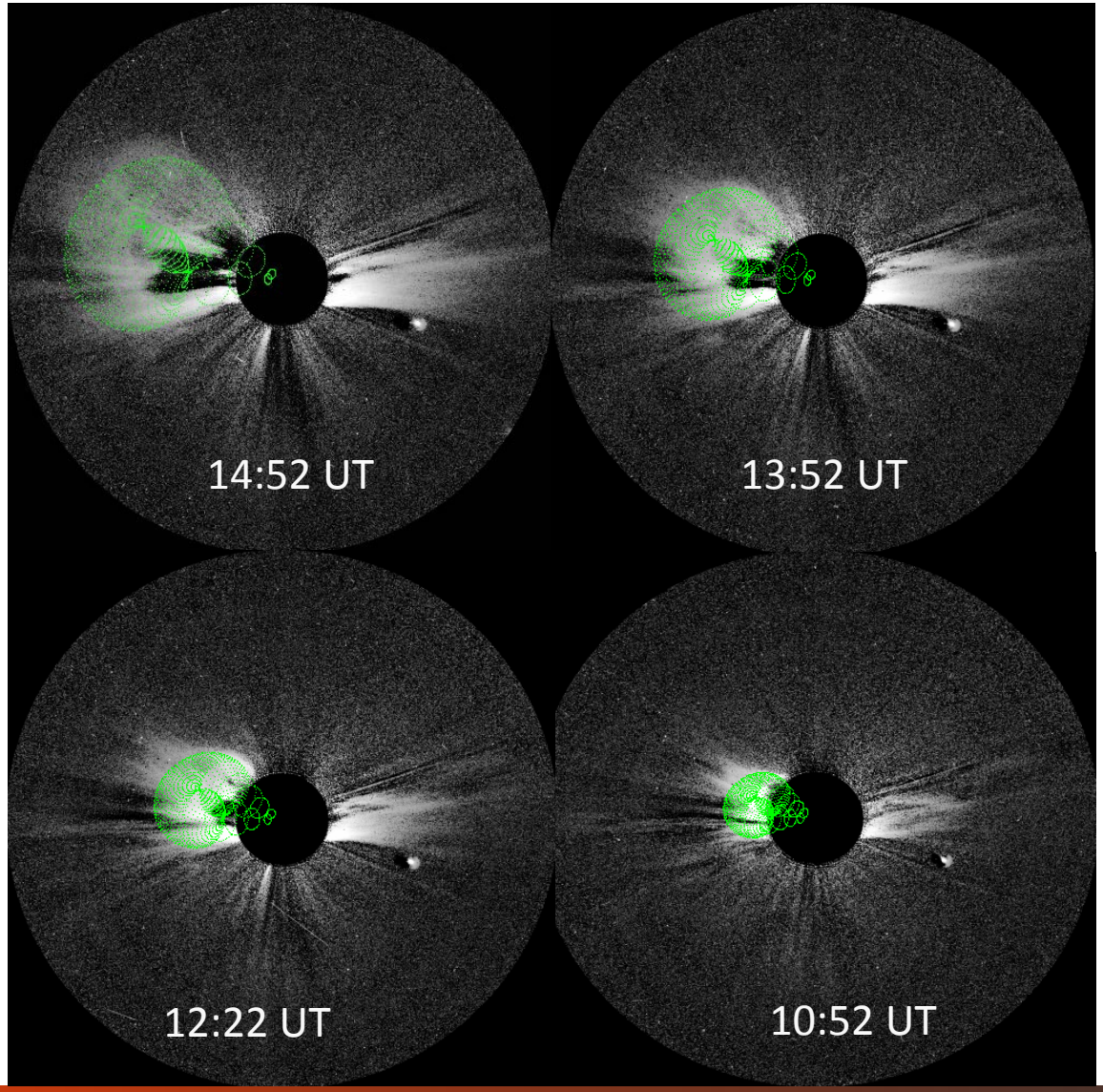
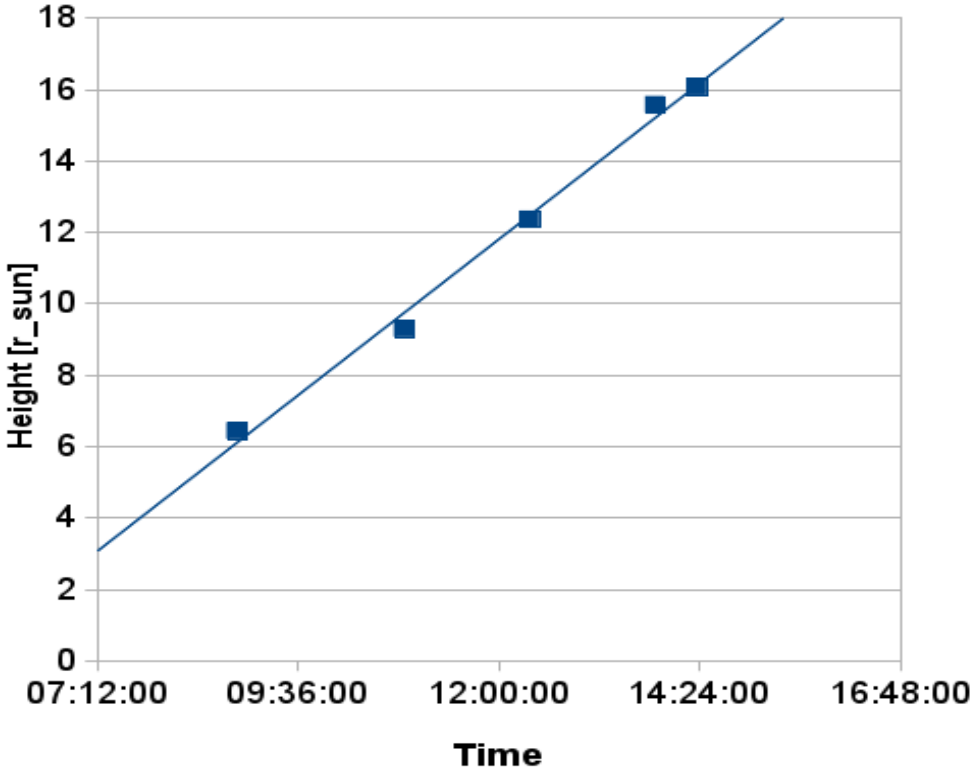
κ = a/r	aspect ratio	σ_t	Gaussian width of density profile inside GCS
N_e	electron density	σ_l	Gaussian width of density profile outside GCS

Sample CME speed determination based on dynamic GCS modelling in COR2 FOV (2.5-15 R_S) – 12 December 2008



Courtesy: E. Bosman

Results for 12 December 2008 event



GCS - FIT

V_{apex} = 321 km/s

Catalogue Speeds HI 1

FPF = 456 km/s
SSEF = 470 km/s
HMF = 481 km/s

Catalogue Speeds

CAT = 420 km/s
SOHO = 203 km/s
SEEDS = 259 (A), 1269 (B)

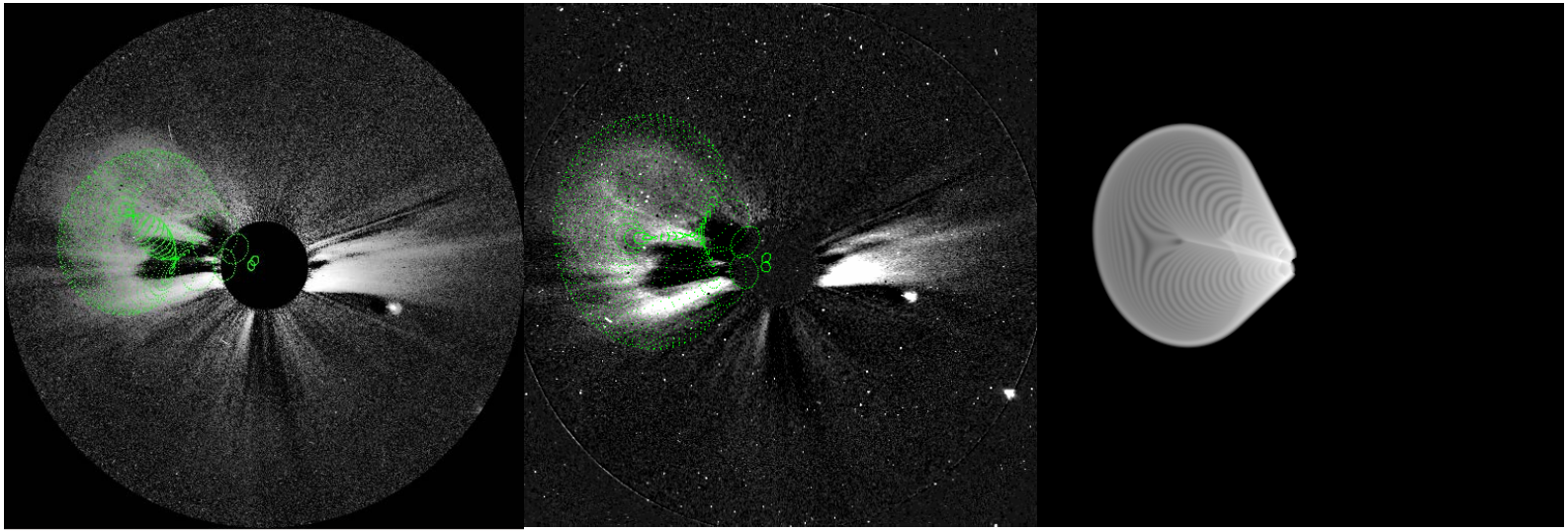
To be further compared with speeds provided in several publications on December event.

Problems in CME speed determinations

- CME deflection leads to Apex shift in PA
- CME distortion can lead to deviations of CME features from fitted flux rope topology
- Dynamic fitting vs. static fitting (SSE)
- Accuracy of fitting depends on viewing angles
- Accuracy of determined CME speeds is lower for faster events
- Possible Apex mismatches with associated shock features

Sample CME mass determination for December event

Ref.: „Determination of the True Mass of Coronal Mass Ejections:
A Novel Approach to Using the Two STEREO Viewpoints“ (Colanino and Vourlidas, 2009).
Comprehensive analysis of cortonal mass ejection mass and energy properties over a full solar cycle (Vourlidas et al., 2010). Collaboration with Neel Savani.



brightness images

mass images

synthetic images

Software: SolarSoft routines, NRL Ray Tracing code

Courtesy: A. Pluta

CME mass determination

Mean solar brightness image - preevent image

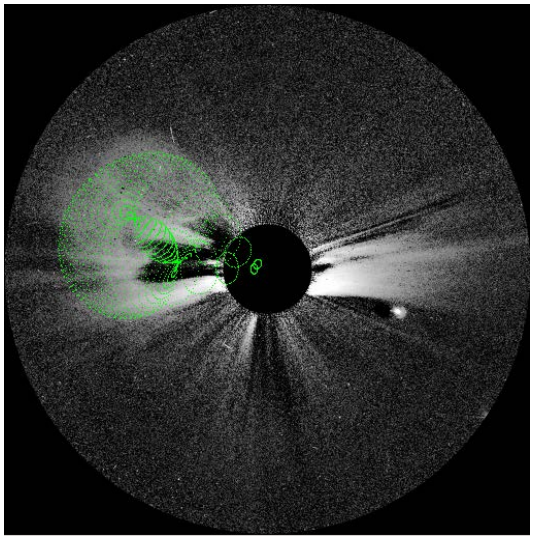
→ Brightness Image

Thomson Scattering:
Intensity depends on angle θ to the POS !

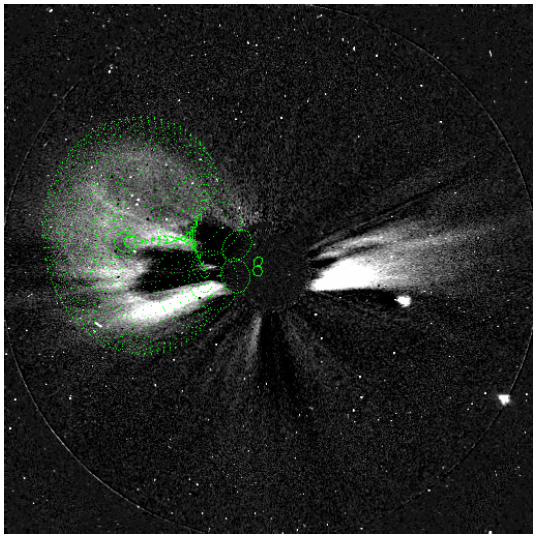
Billings equation(1966) → B_e (θ)

$$m = \frac{B_{obs}}{B_e(\theta)} \times 1.97 \times 10^{-24} g$$

→ Mass Image

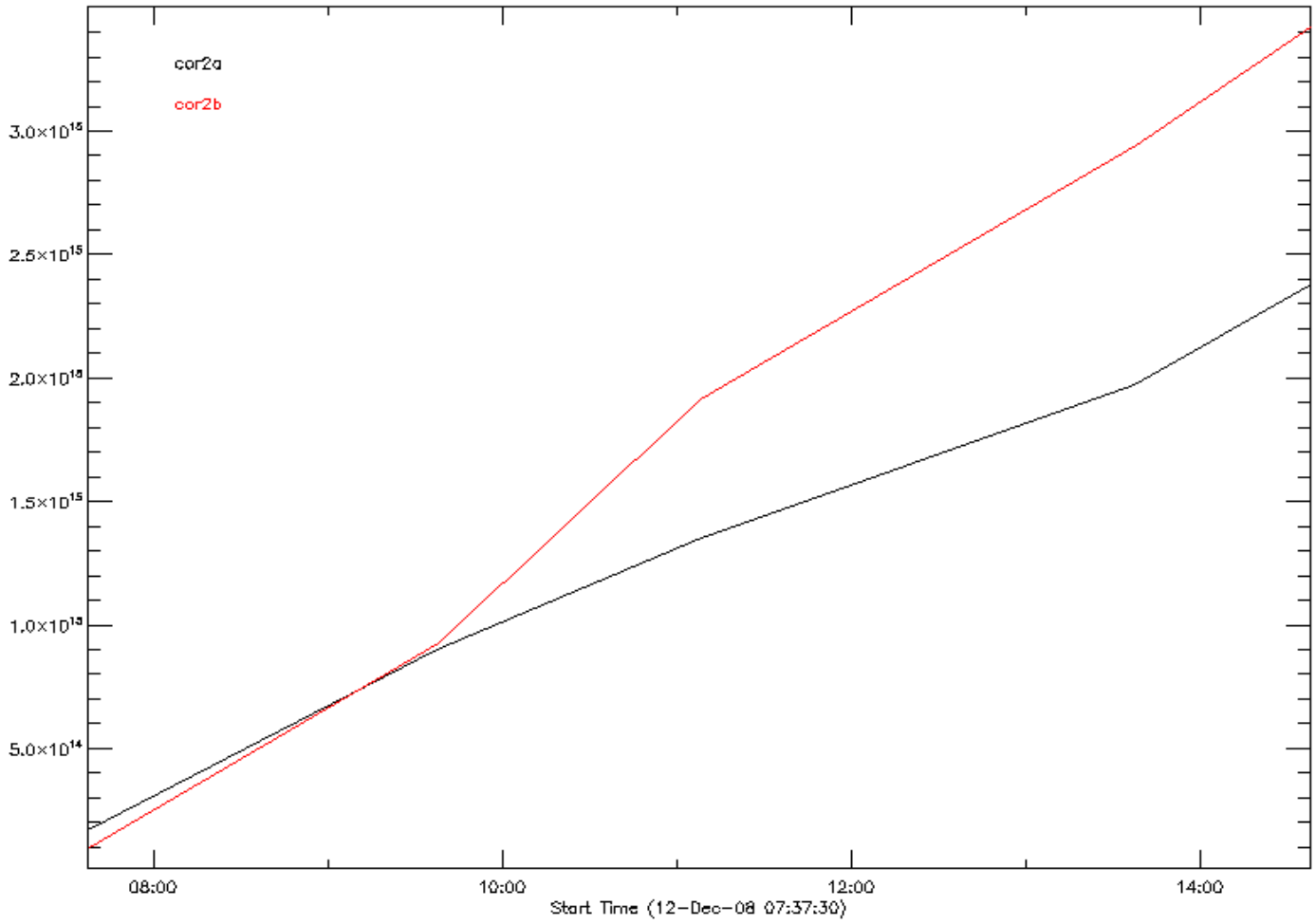


Brightness Image



Mass Image

Results for STEREO/SECCHI/COR2 A and B



Problems in CME mass determinations

- CME distortion can lead to deviations of CME features from fitted flux rope topology
- Possible Apex mismatches with associated shock features
- Accuracy depends on viewing angle and position of STEREO A and B
- CME has 3D structure, leading to a superposition of viewing angles

Update inverse modelling of STEREO/HI CMEs (Task leader: UGOE; Additional partner: 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

- List of STEREO/SECCHI HI shock-driving CMEs sent to WP3 members (Laura Volpes, see also contribution to WP4)
- Placed online by TCD @ http://grian.phy.tcd.ie/helcats/
- as low coronal event catalogue

Low coronal event list

Low Coronal Event Catalogue

Some introduction about this table and its contents.

<1> No.	<2> Event Date	<3> NOAA Region (location)	<4> GOES Class	<5> Flare Time (Start, Peak, End) UT	<6> Hale Class	<7> EUV Wave (EUV Filter Å)	<8> CME (Time, speed, movies)	<9> Radio (NRH, DAM, Callisto)	<10> X-ray (RHESSI, FERMI)	<11> Maps (Desnity, PFSS, Alfven speed)
1	2010-Apr-03	11059 (S25W03)	B7.4	(09:04, HH:MM HH:MM)	β	None	10:33 UT 668 km/s CME Catalogue	Type II(?) Type III NRH 150 MHz	FERMI	Soon
2	2011-Jun-07	11226 (S22W66)	M2.5	(06:16, 06:30, 06:41)	β	HEK AIA 171, 193, 211	06:49 UT 1255 km/s CDAW Cactus	Complex	RHESSI FERMI	Soon
3	2011-Aug-03	11261 (N16W28)	M6.0	(13:17, 13:48, 14:10)	βγδ	HEK AIA 211	14:00 UT 610 km/s CDAW Cactus	Type II, III, IV NRH 150 MHz NRH 445 MHz	RHESSI	Soon
4	2012-Jan-19	11402 (N32E27)	M2.6	(13:43, 15:30, 16:30)	βγ	None	14:36 UT 1120 km/s CDAW Cactus CORIMP	Type II, III NRH 150 MHz NRH 432 MHz	N/A	Soon