A summary of WG5 (and related) activities:

The Bs Challenge

Spiros Patsourakos, University of Ioannina, Greece

The Bs challenge: Statement of the WG
(from ISEST description)

The presence of **southward** magnetic fields in ICMEs are
the most important factor in producing **geomagnetic storms**.

The challenge is that direct observations of magnetic fields near the Sun
are extremely limited: currently possible only in the
photosphere/chromosphere
at the solar end and by in-situ observations at 1 AU.

WG5 aims to understand and reconstruct the possible flux
rope **magnetic structure**
of CMEs/ICMEs from observations and models. It also aims to
predict the **intensity** and the duration of the **Bs** in ICMEs
upon arriving at the Earth.

Direct “diagnostics” of near-Sun & IP CME magnetic fields in the radio domain

Faraday rotation (e.g.,Bird et al. 1985; Jensen & Russel 2008, Liu et al. 2007, Jensen et al. 2010; Liu et al. 2007; Bisi et al 2016; Kooi et al. 2017)

gyrosynchrotron emission (e.g., Bastian et al. 2001;Tun & Vourlidas 2013)

direct access to CME magnetic fields

(talks by B. Jackson **(and CSSS+IPS)**, I. Cairns, ...)

Difficult Observations

Indirect Methods of near-Sun CME B-field Determination

Need robust methods that could be applied on more regular basis

These methods are based on empirical modeling of CME observations

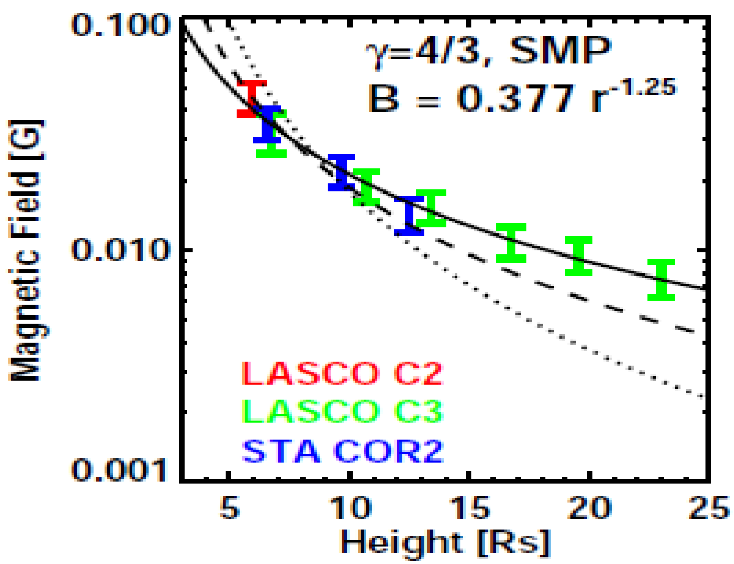
CME-driven shocks

(1) shock stand-off distance from CME/shock WL/EUV observations & WL densities

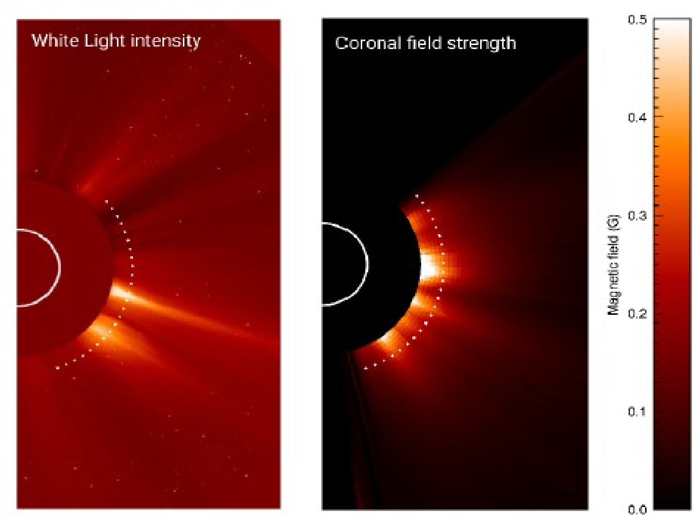
(2) jump conditions & WL densities

→ *|B| in **sheath** & background*

(*e.g., Vrsnak et al. 2002,* Bemporad & Mancuso 2011; Zucca et al. 2014)



Gopalswamy & Yashiro 2011



Bemporad et al. 2015

Helicity method H-CME

Patsourakos, Georgoulis, Vourlidas et al. (2016);
Patsourakos & Georgoulis (2016, 2017)

For LFF cylindrical flux rope (Lundquist 1950) :
Dasso, Mandrini, Demoulin et al. 2003 →

$$B_0 = \sqrt{\frac{2.405 H_m}{4\pi L R J}}$$

L, R → CME length+ radius from GCS
modeling of CMEs with STEREO (Thernisien et al 2009)

Hm → source-region or eruption-related magnetic helicity from photospheric magnetic/flow obs & extrapolations
(reviews of methods by Valori et al. 2017; Guo et al. 2017; Pariat et al. 2017; Georgoulis et al. 2017)

Hm is conserved even with reconnection
(Berger 1985; Pariat et al. 2016)

All input parameters can be determined in a routine base

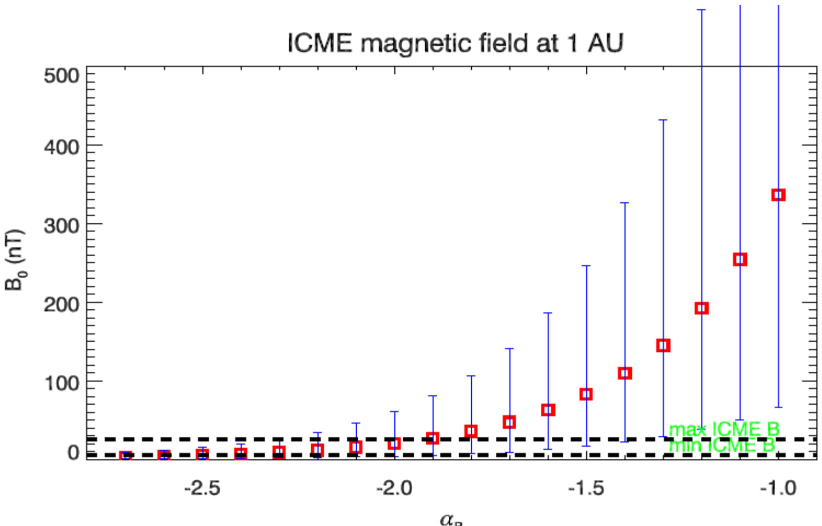
Extrapolation of near-Sun magnetic field to 1 AU

Use a power-law of the radial distance r:

$$B_0(r) = B_*(r/r_*)^{\alpha_B}$$

αB-range from Demoulin & Dasso 2009
compilation of observations & models → [-2.7, -1.0]

CME b-field magnitude at 1 AU



Application to a case study

Boxes ---> model
Horizontal lines ---> ICME |B|

Patsourakos +2016

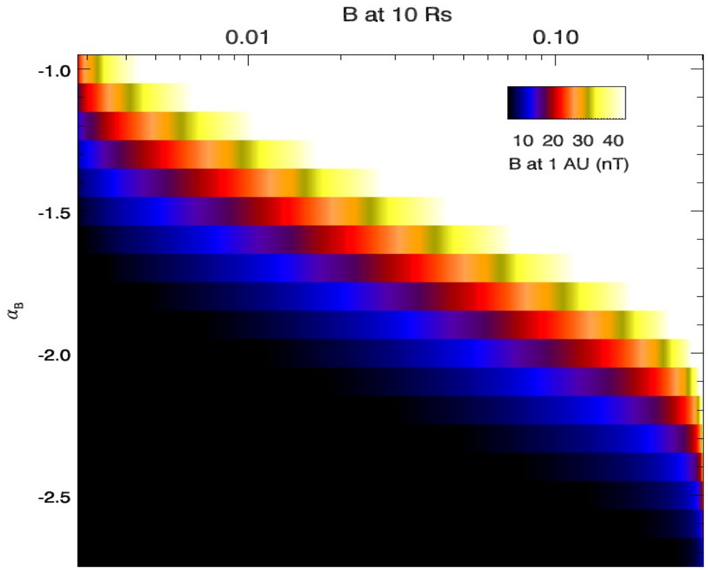
Parametric Studies of H-CME *(Patsourakos, Geourgoulis 2016,2017)*

Randomly pick up 10^4 values from the observed AR Hm (Tziotziou et al. 2012) & CME geometrical parameters (Thernisien, Vourlidas & Howard 2009; Bosman et al. 2012) distributions

Determine near-Sun B for the 10^4 synthetic CMEs*

Extrapolate CME b-field to 1 AU for different αB for the 10^4 synthetic CMEs

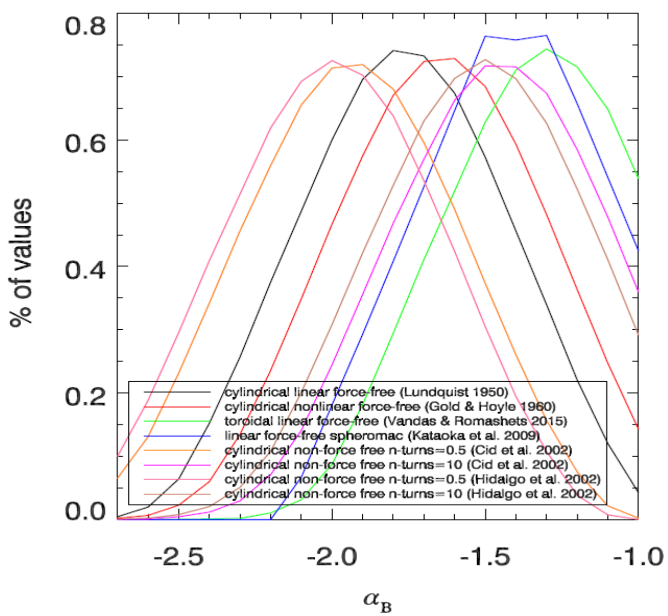
Parametric Studies of H-CME



colored --> extrapolated to 1 AU CME magnetic field

black+white ---> outside range of MC observations (Lynch et al. 2003; Lepping et al. 2006)

αB~-1.6 fits reproduces the bulk of MC observations

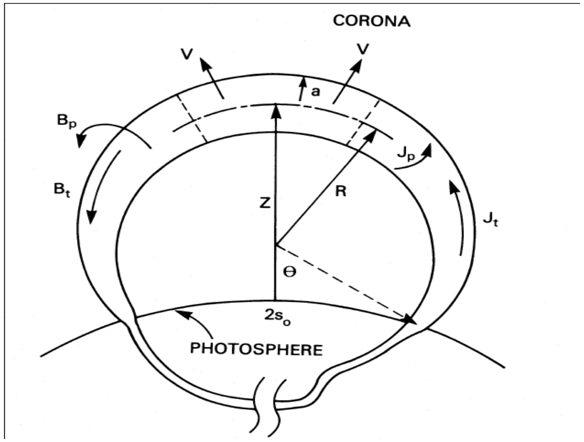


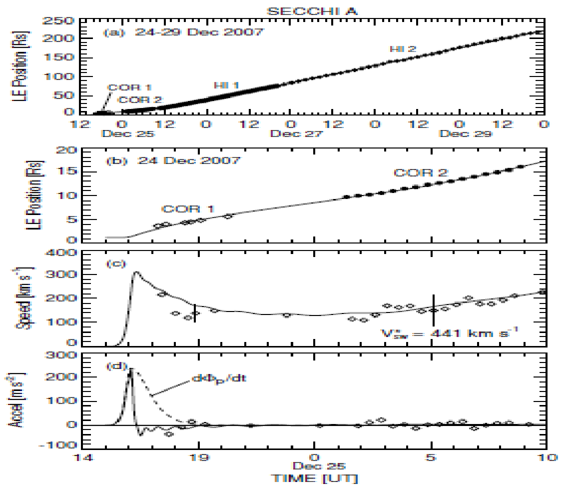
Extension to various CME models (e.g., non-force-free, spheromac etc)

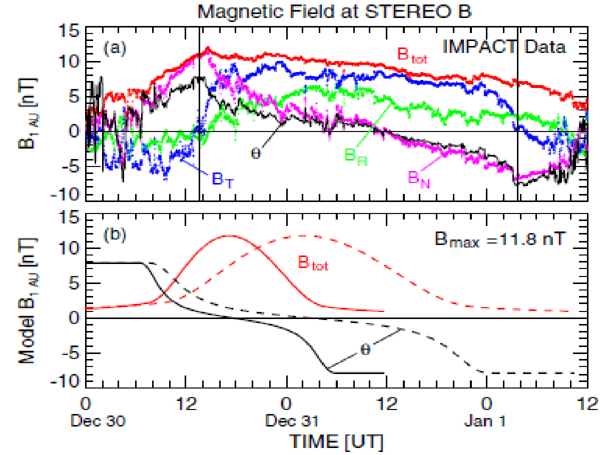
% of predicted values within the range of MC observations as a function of α_B

Robustness of models

Flux rope method







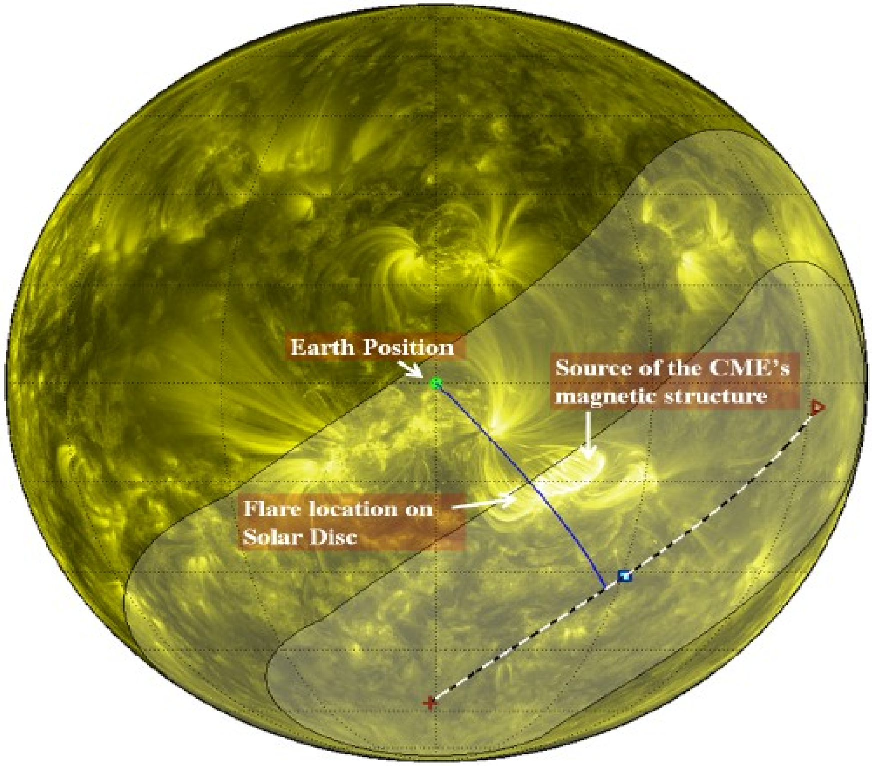
Chen (1989); Kunkel & Chen (2010), Roulliard & Kunkel (2014)

Use observed h-t of a CME to determine its poloidal flux injection profile to match the flux rope kinematics
→ B at all distances

one case study
Schuck (2011): difficulties with poloidal flux injection in the photosphere
Adequate propagation model

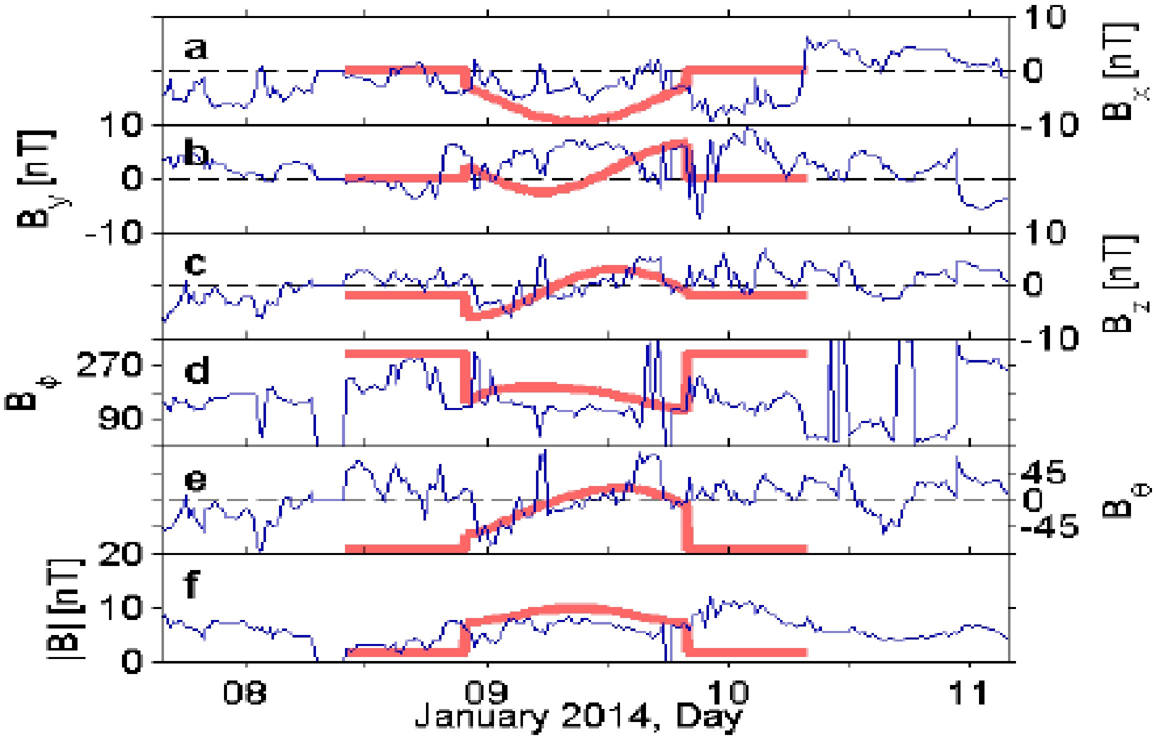
BZ4CAST (Savani et al. 2015, 2016)

Use GCS fittings (CME width and axis orientation)
→ determine volume of influence of the CME-ICME in the heliosphere



BZ4CAST-cont

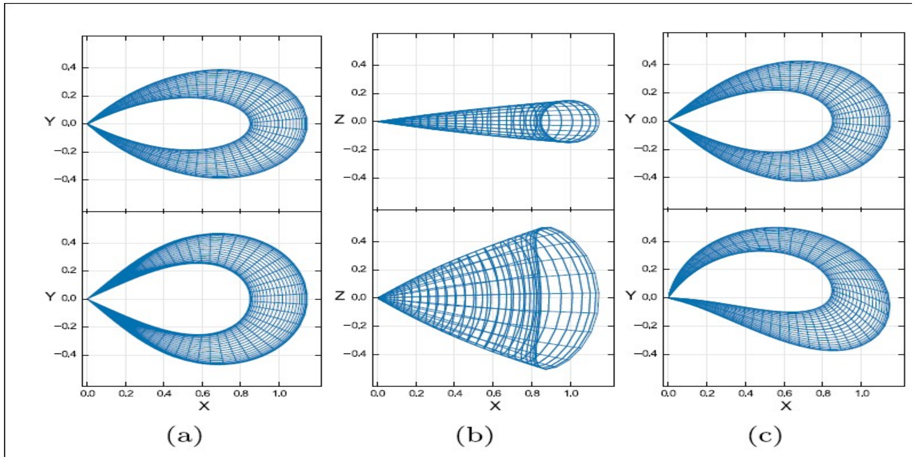
Hm sign of source region, axis orientation & impact parameter
→ Bvec @ 1 AU *applied to 8 events*



red ---> model

ENLIL simulations are used to predict the CME magnetic field @ 1AU

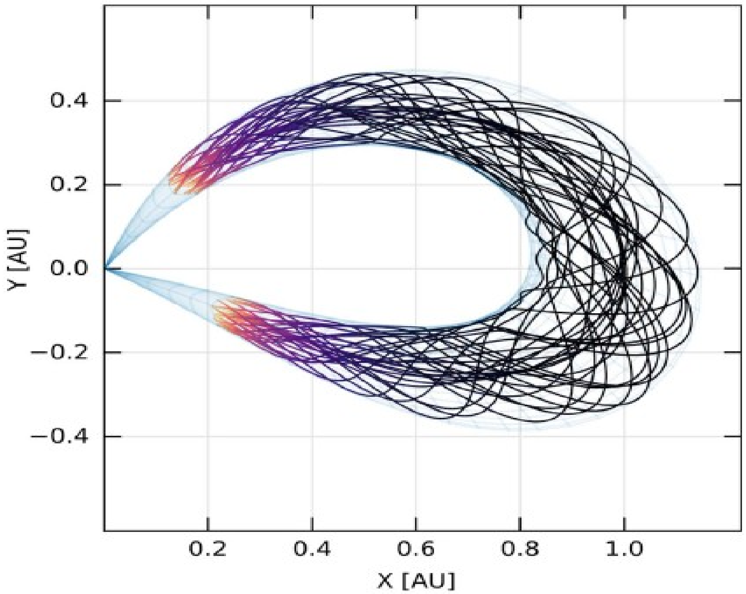
FriED (Isavnin 2016)



Generalization of GCS model to deal with CME deformations (skewing, panckaking)

+

Populates GCS with magnetic field structure from LFF

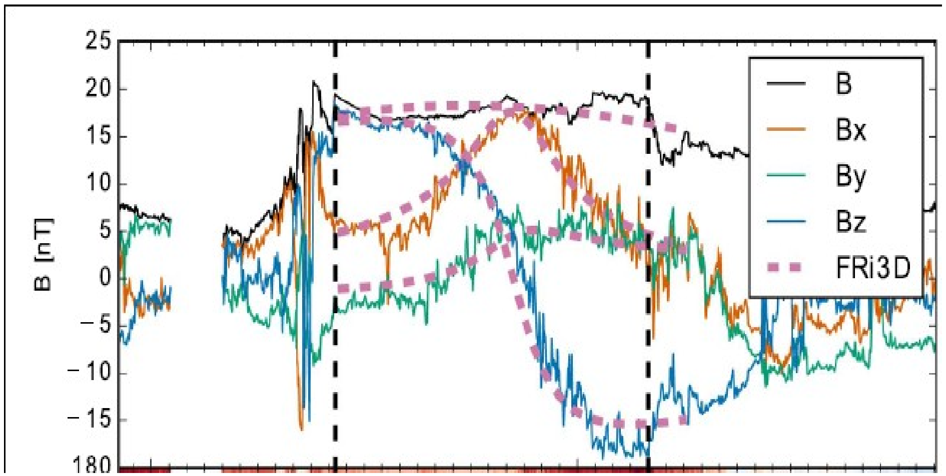


FriED (Isavnin 2016)

flux conservation --->
CME magnetic field @ 1 AU

applied to a case study

Dashes ---> model



Uses in-situ observations @ 1 AU to determine near-Sun CME |B|

FIDO (Kay et al. 2017)

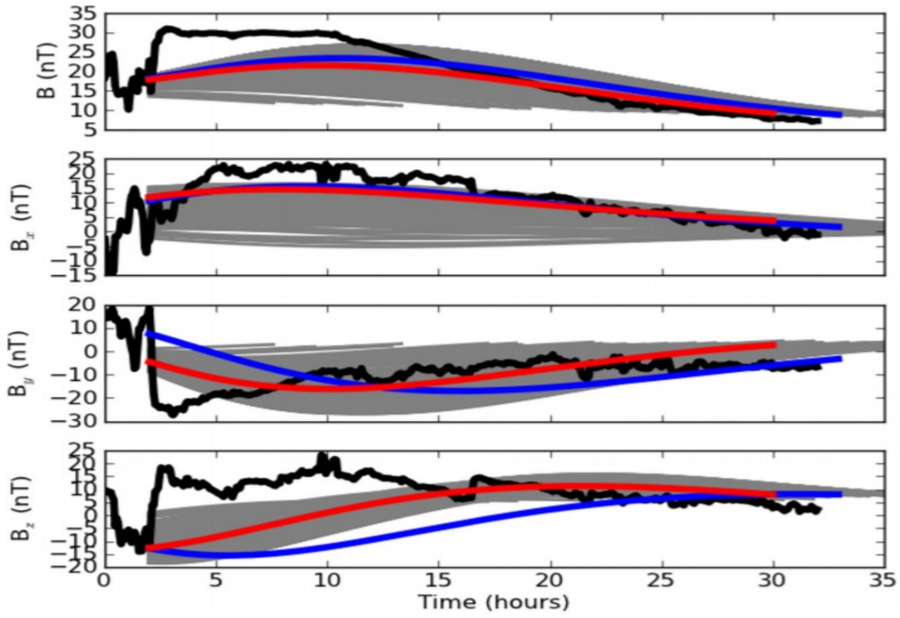
Analytical data-constrained model (Kay et al. 2013,2014,2015)

magnetic forces acting on CMEs --> near-Sun CME deflection + rotation

LFF model + flux conservation --> B CME @ 1 AU

FIDO (Kay et al. 2017)

Applied to 4 events

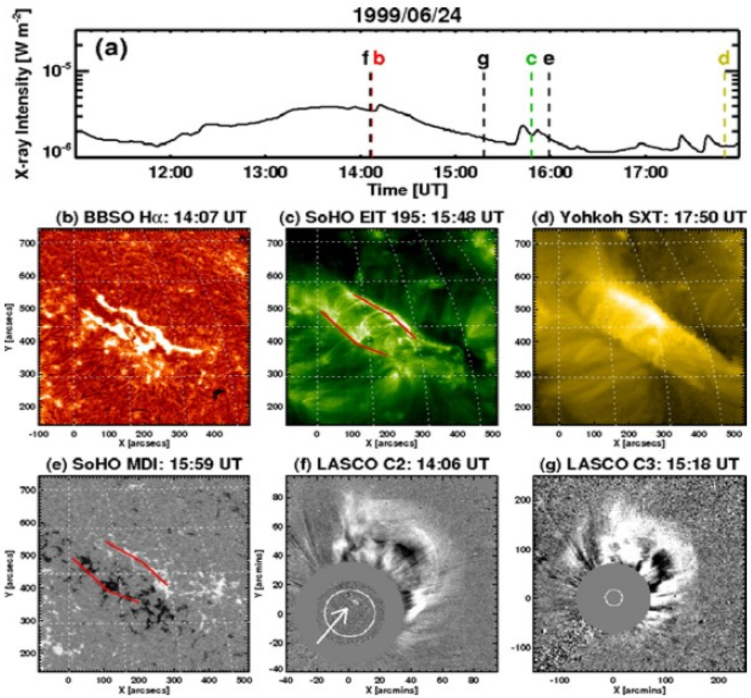


black ---> observations

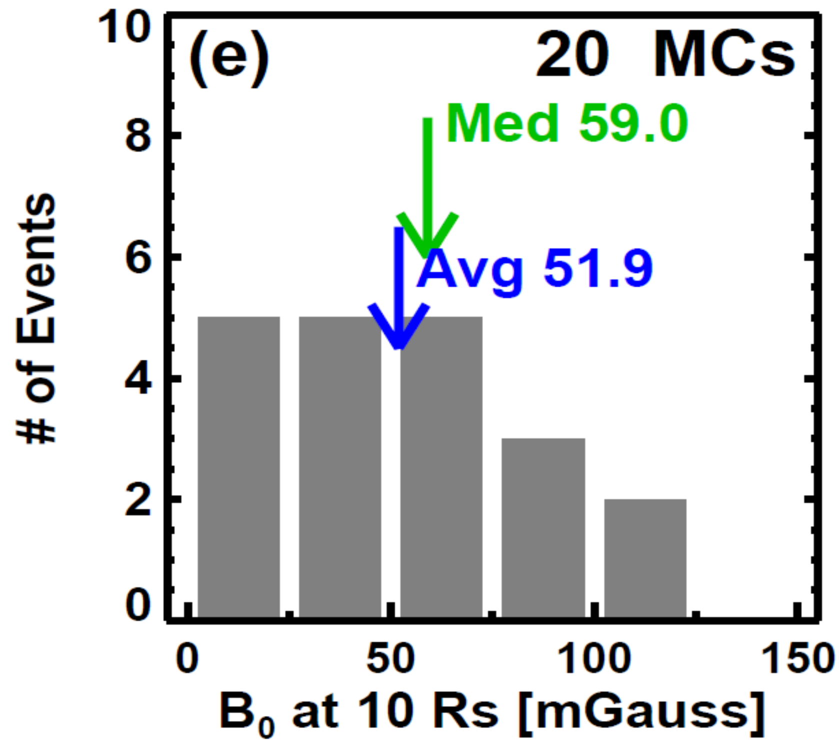
red ---> model

Uses in-situ observations @ 1 AU for near-Sun |B|

FRED (Gopalswamy et al. 2017)

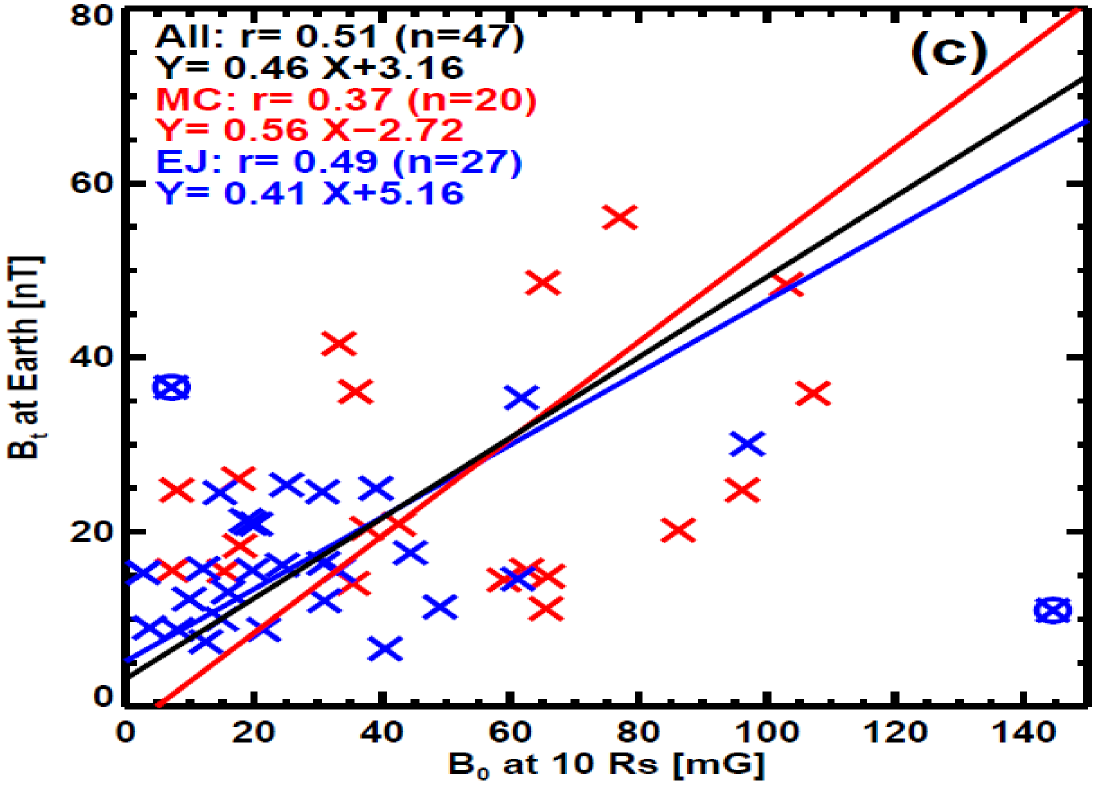


Calculate **reconnected flux** in post-eruption arcades
+ fit **flux rope model**
to corresponding CMEs from LASCO observations of 54 CMEs



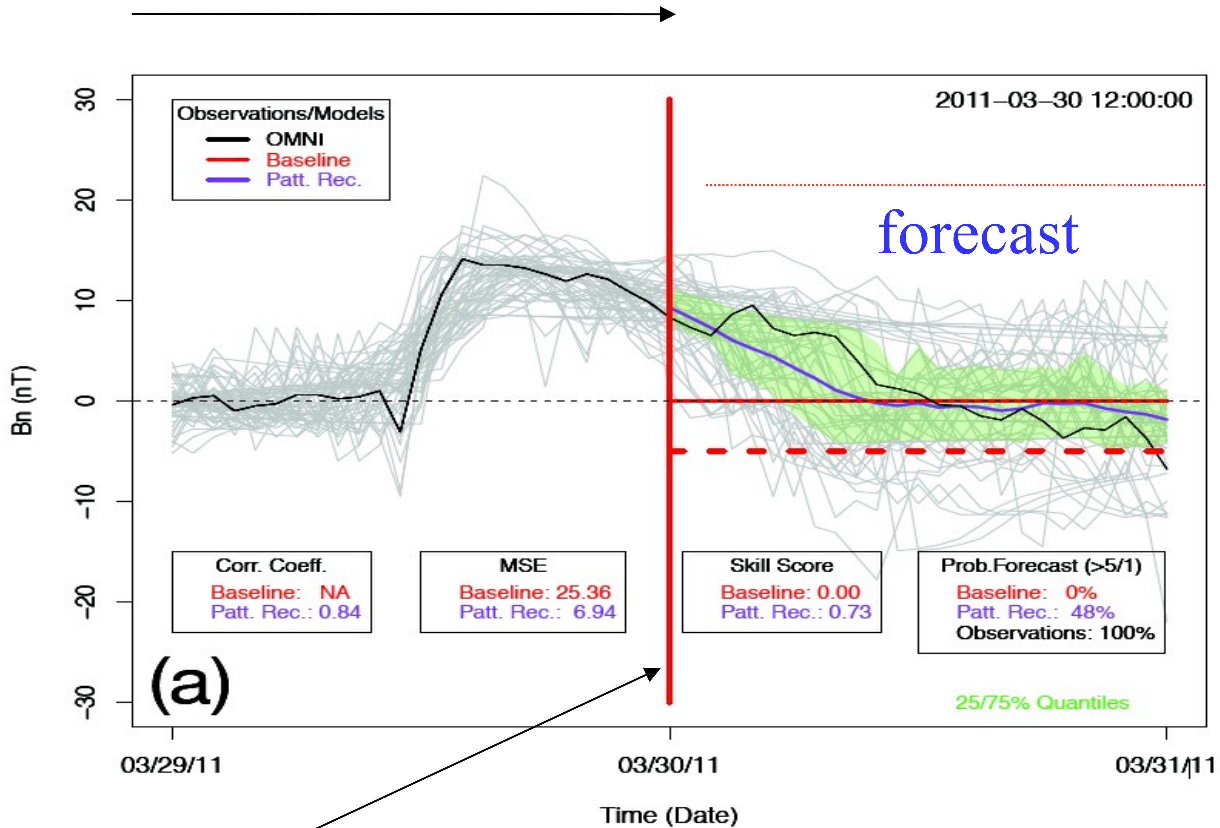
Apply constraints to Lundquist model ---> CME magnetic fields at 10 Rs (> ambient)

FRED: Coronal and IP attributes (Gopalswamy et al. 2017)



Good correlation btw Coronal BCME +MC axial field from Marubashi et al. (2015)

Pattern Recognition (Riley et al. 2017)



Set **reference time** & **define window dt in past**

Search 10 years of in-situ data for 50 best dt-long intervals & use their next dt for forecast

Good match between forecast + observations

Part of the MC should be already observed

Conclusions

No perfect model currently exists

Progress but need to do much more ....

Actions

Test various existing models on the same events

Parametric studies of the various methods

Come up with hybrid schemes + exploit radio + IPS

Collaborate with other WGs (e.g., modeling) for CME rotation

Collaborate with other teams (e.g., International Forum for Space Weather Capabilities Assessment @ CCMC: IMF Bz at L1 Working Team; KSWRS; Euphoria; CESE-AMR; SUNSANOO; ENLIL)

Populate our list of events

GEORGE MASON UNIVERSITY

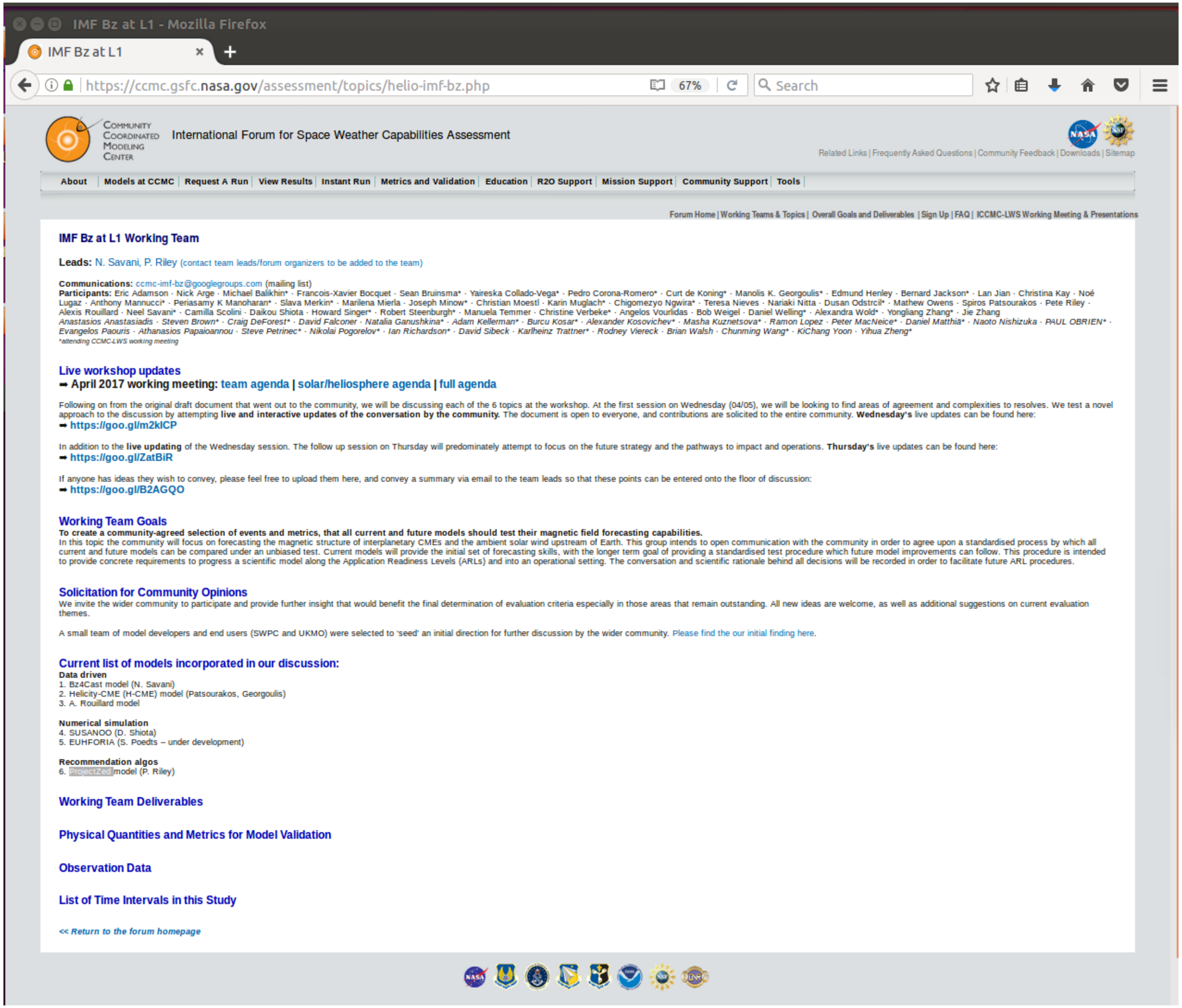
Overview
Data, Campaigns, WGs
ICME\CME Lists
Event Data
WG1 (data)
WG2 (theory)
WG3 (simulation)
WG4 (Campaign)
WG5 (Bs)
WG6 (SEP)
MiniMax24
varSITI Campaign
Workshops
2013 Workshop
2014 Workshop
2015 Workshop
Additional Resources
Papers
Useful Links
Maintenance
Navigation
Main page
Help
Recent changes
Random page
Upload Video File
Tools
What links here
Related changes
Special pages
Printable version
Permanent link
Page information

List of CMEs for WG5 Analysis

List of near-Sun Observations/Determinations of CME Magnetic Fields for WG5

Date and Time	Solar Source (AR # or location)	Method of Magnetic Field Determination	Publication	Miscellaneous	Submitter contact
2011/06/07 06:47 UT	AR NOAA 11226 (CME propagating on the west limb)	The magnetic field in the corona is determined by applying the Rankine-Hugoniot equations to LASCO C2 and C3 white-light images of the CME-driven shock in order to derive a map of the shock Alfvenic Mach number	Bemporad, A. & Mancuso, S. 2010, ApJ 720, 130 (also Bemporad, A., Susino, R., & Mancso, S. ApJ, in preparation)		R. Susino (susino@oato.inaf.it) and A. Bemporad (bemporad@oato.inaf.it)}
2012/03/07 01:14 UT	AR NOAA 11429	The coronal CME magnetic field is estimated by combination of magnetic helicity calculations of the CME source region and forward modeling of the CME along with application of the helicity conservation principle in flux-rope CMEs	Patsourakos, S., Georgoulis, M. K., Vourlidas, A. et al., 2016, ApJ, 817, 14		S. Patsourakos (spatsour@cc.uoi.gr)}

International Forum for Space Weather Capabilities Assessment @ CCMC: IMF Bz at L1 Working Team



IMF Bz at L1 - Mozilla Firefox

IMF Bz at L1

https://ccmc.gsfc.nasa.gov/assessment/topics/helio-imf-bz.php

COMMUNITY COORDINATED MODELING CENTER

International Forum for Space Weather Capabilities Assessment

Related Links | Frequently Asked Questions | Community Feedback | Downloads | Sitemap

About | Models at CCMC | Request A Run | View Results | Instant Run | Metrics and Validation | Education | R2O Support | Mission Support | Community Support | Tools |

Forum Home | Working Teams & Topics | Overall Goals and Deliverables | Sign Up | FAQ | ICCMC-LWS Working Meeting & Presentations

IMF Bz at L1 Working Team

Leads: N. Savani, P. Riley (contact team leads/forum organizers to be added to the team)

Communications: ccmc-imf-bz@googlegroups.com (mailing list)
Participants: Eric Adamson · Nick Arge · Michael Balikhin* · Francois-Xavier Bocquet · Sean Bruinsma* · Yaireska Collado-Vega* · Pedro Corona-Romero* · Curt de Koning* · Manolis K. Georgoulis* · Edmund Henley · Bernard Jackson* · Lan Jian · Christina Kay · Noé Lugaz · Anthony Mannucci* · Periasamy K Manoharan* · Slava Merkin* · Marilena Mierla · Joseph Minow* · Christian Moestl · Karin Muglach* · Chigomezyo Ngwira* · Teresa Nieves · Nariaki Nitta · Dusan Odstrcil* · Mathew Owens · Spiros Patsourakos · Pete Riley · Alexis Rouillard · Neel Savani* · Camilla Scolini · Daikou Shiota · Howard Singer* · Robert Steenburgh* · Manuela Temmer · Christine Verbeke* · Angelos Vourlidas · Bob Weigel · Daniel Welling* · Alexandra Wold* · Yongliang Zhang* · Jie Zhang
Anastasios Anastasiadis · Steven Brown · Craig DeForest* · David Falconer · Natalia Ganushkina* · Adam Kellerman* · Burcu Kosar* · Alexander Kosovichev* · Masha Kuznetsova* · Ramon Lopez · Peter MacNeice* · Daniel Matthiä* · Naoto Nishizuka · PAUL OBRIEN* · Evangelos Paouris · Athanasios Papaioannou · Steve Petrinec* · Nikolai Pogorelov* · Ian Richardson* · David Sibeck · Karlheinz Trattner* · Rodney Viereck · Brian Walsh · Chunming Wang* · KiChang Yoon · Yihua Zheng**
*attending CCMC-LWS working meeting

Live workshop updates

➡ **April 2017 working meeting:** team agenda | solar/heliosphere agenda | full agenda

Following on from the original draft document that went out to the community, we will be discussing each of the 6 topics at the workshop. At the first session on Wednesday (04/05), we will be looking to find areas of agreement and complexities to resolves. We test a novel approach to the discussion by attempting **live and interactive updates of the conversation by the community.** The document is open to everyone, and contributions are solicited to the entire community. **Wednesday's** live updates can be found here:
➡ https://goo.gl/m2kICP

In addition to the **live updating** of the Wednesday session. The follow up session on Thursday will predominately attempt to focus on the future strategy and the pathways to impact and operations. **Thursday's** live updates can be found here:
➡ https://goo.gl/ZatBiR

If anyone has ideas they wish to convey, please feel free to upload them here, and convey a summary via email to the team leads so that these points can be entered onto the floor of discussion:
➡ https://goo.gl/B2AGQO

Working Team Goals

To create a community-agreed selection of events and metrics, that all current and future models should test their magnetic field forecasting capabilities.
In this topic the community will focus on forecasting the magnetic structure of interplanetary CMEs and the ambient solar wind upstream of Earth. This group intends to open communication with the community in order to agree upon a standardised process by which all current and future models can be compared under an unbiased test. Current models will provide the initial set of forecasting skills, with the longer term goal of providing a standardised test procedure which future model improvements can follow. This procedure is intended to provide concrete requirements to progress a scientific model along the Application Readiness Levels (ARLs) and into an operational setting. The conversation and scientific rationale behind all decisions will be recorded in order to facilitate future ARL procedures.

Solicitation for Community Opinions

We invite the wider community to participate and provide further insight that would benefit the final determination of evaluation criteria especially in those areas that remain outstanding. All new ideas are welcome, as well as additional suggestions on current evaluation themes.

A small team of model developers and end users (SWPC and UKMO) were selected to 'seed' an initial direction for further discussion by the wider community. Please find the our initial finding here.

Current list of models incorporated in our discussion:

Data driven
1. Bz4Cast model (N. Savani)
2. Helicity-CME (H-CME) model (Patsourakos, Georgoulis)
3. A. Rouillard model

Numerical simulation
4. SUSANOO (D. Shiota)
5. EUHFORIA (S. Poedts – under development)

Recommendation algos
6. ProjectZed model (P. Riley)

Working Team Deliverables

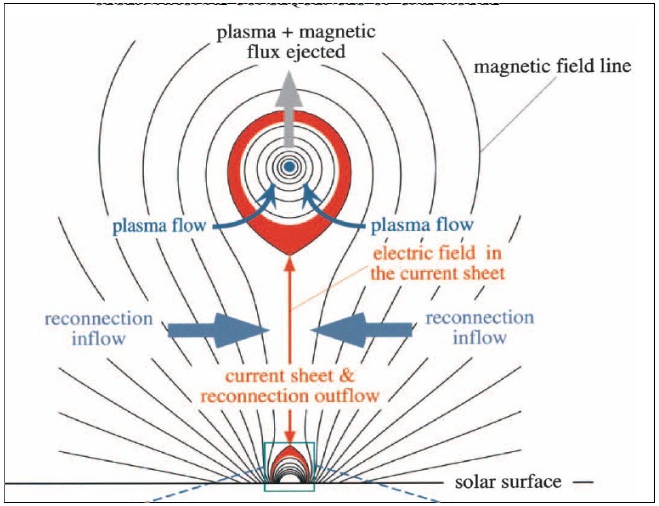
Physical Quantities and Metrics for Model Validation

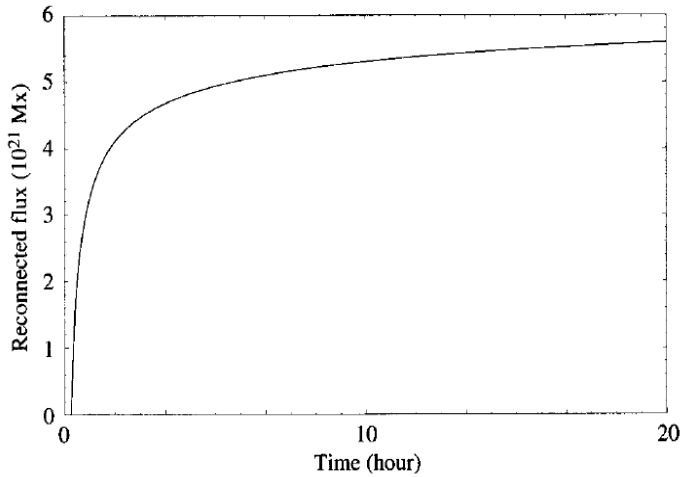
Observation Data

List of Time Intervals in this Study

<< Return to the forum homepage

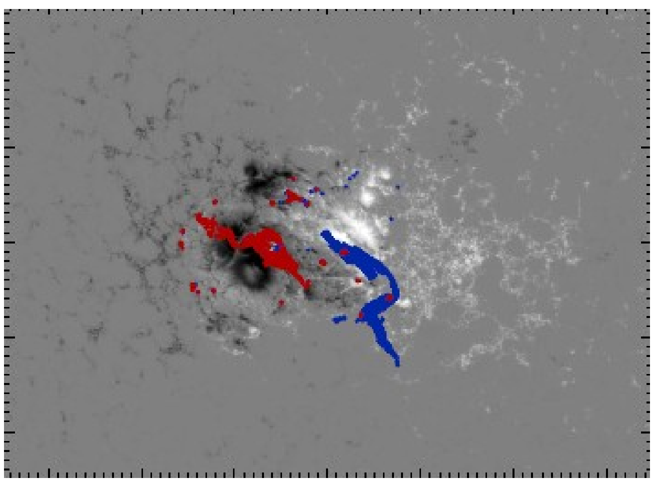
Most CME b-flux is added by reconnection <u>during</u> the eruption

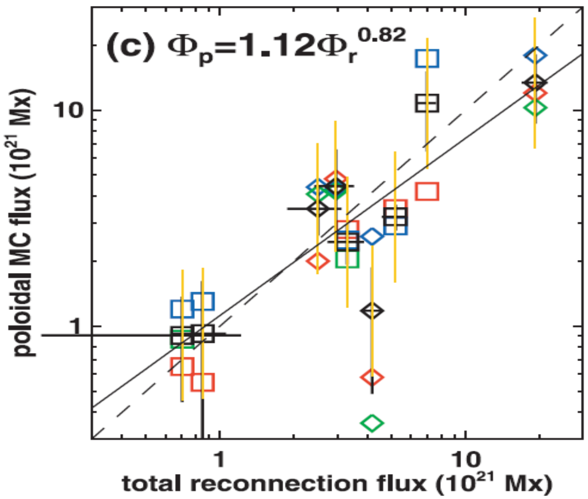




Lin et al. 2004

Vrsank 2008





Qiu et al. 2004, **2007**

Moestl et al. 2009

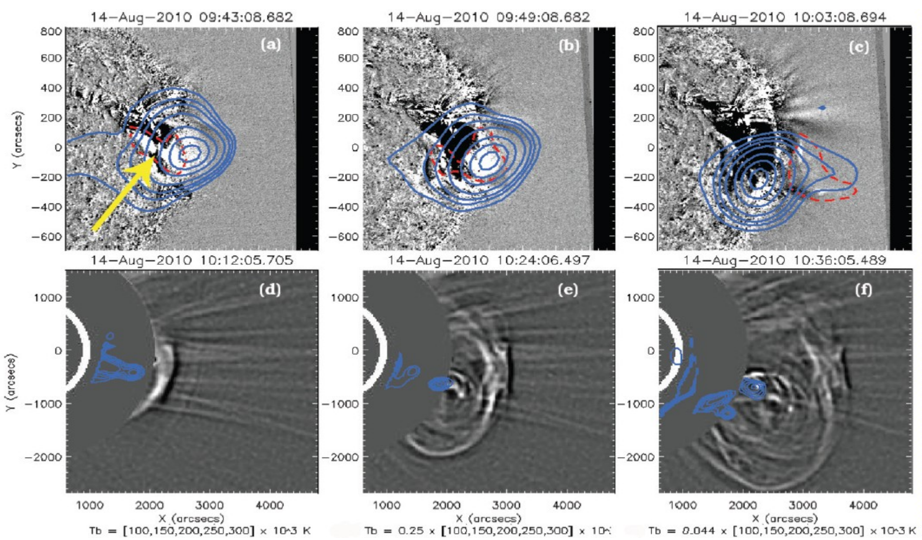
Hu et al. 2014

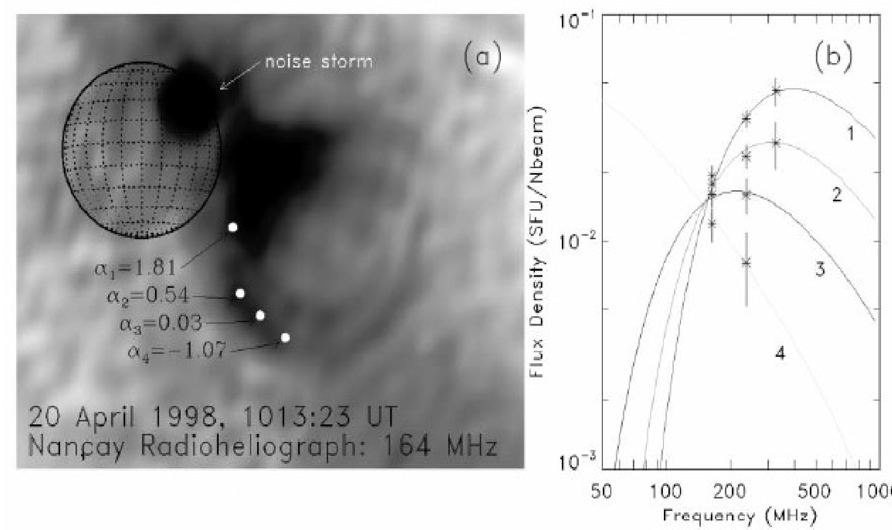
Veronig & Polanec 2015

Pre-eruptive b-field configuration yields only some hints on the erupting structure b-field configuration

Spectral Imaging of moving metric Type IV radio bursts

Fit observed spectrum with gyrosynchrotron emission spectrum



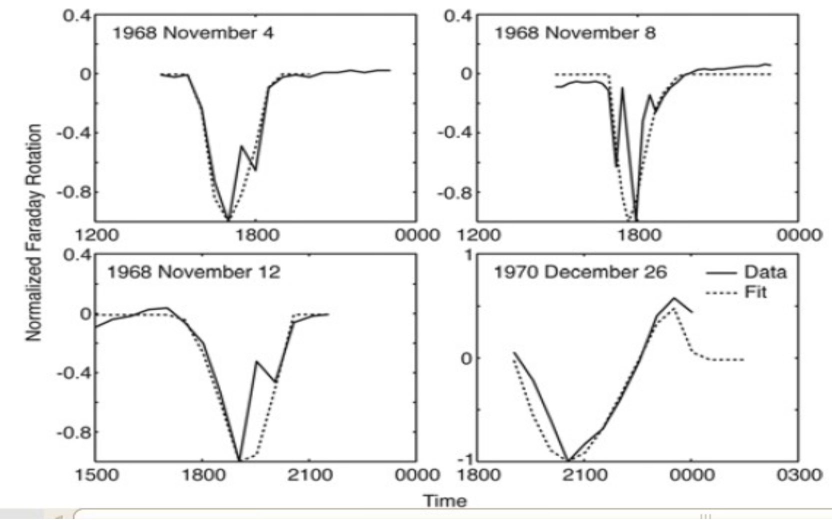


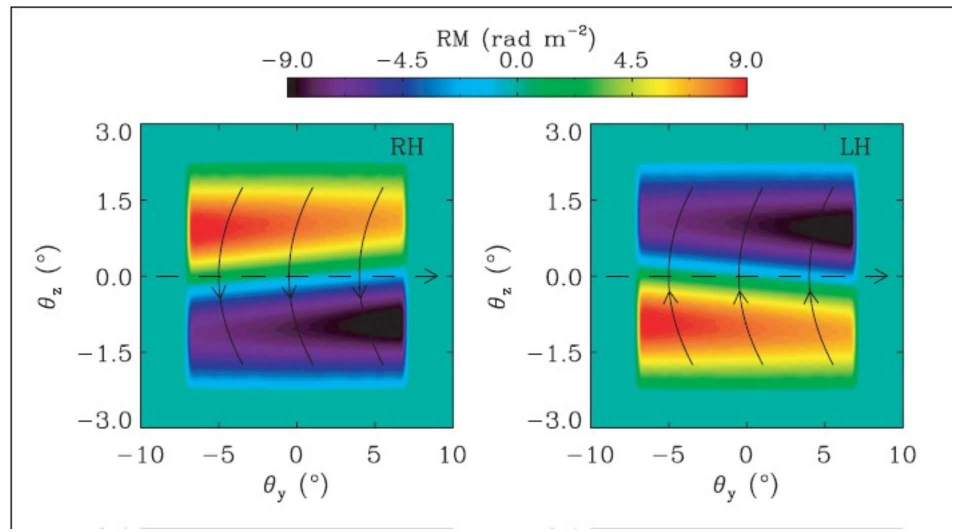
e.g., **Bastian et al. 2001**;**Tun & Vourlidas 2013**

rare observations

Faraday Rotation

Faraday rotation of EM radiation of spacecraft/natural(e.g., pulsar) source through a CME (+ne) → |B|





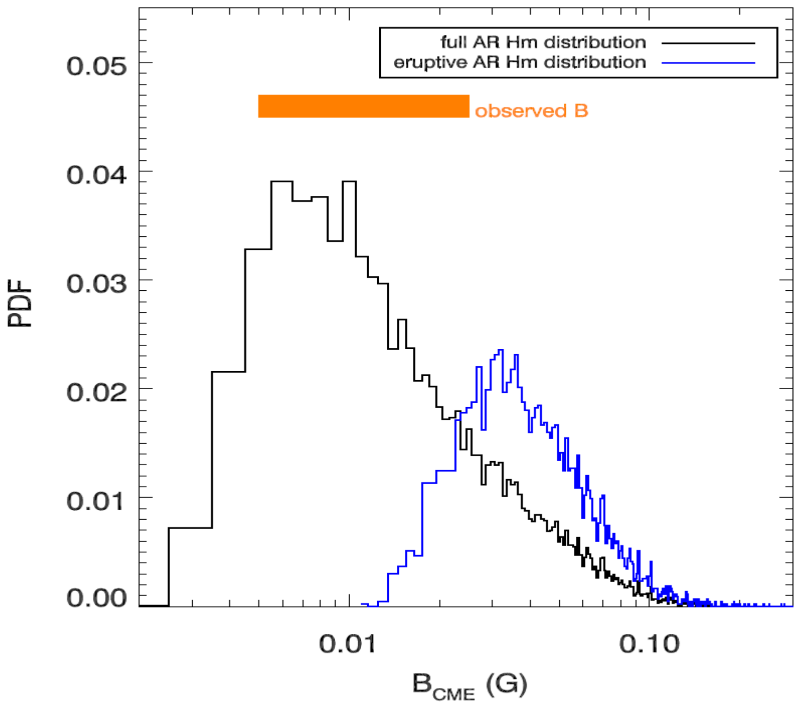
e.g., Bird et al. 1985; **Jensen & Russel 2008**, Kooi et al. 2017

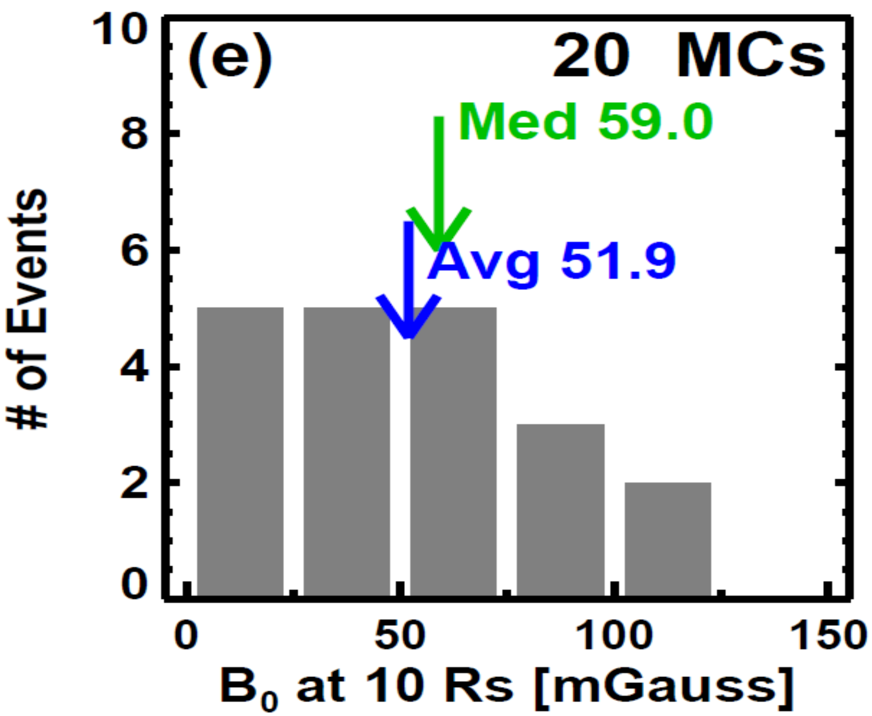
Rare observations

Problems with ionospheric background for ground-based observations

Single LOS issues with CME orientation/handedness (removed by multiple-LOS **Liu et al. 2007**, Jensen et al. 2010, Xiong et al. 2013)

Benchmarking of Methods





Patsourakos & Georgoulis (2016)

Gopalswamy et al (2017)

Work plan

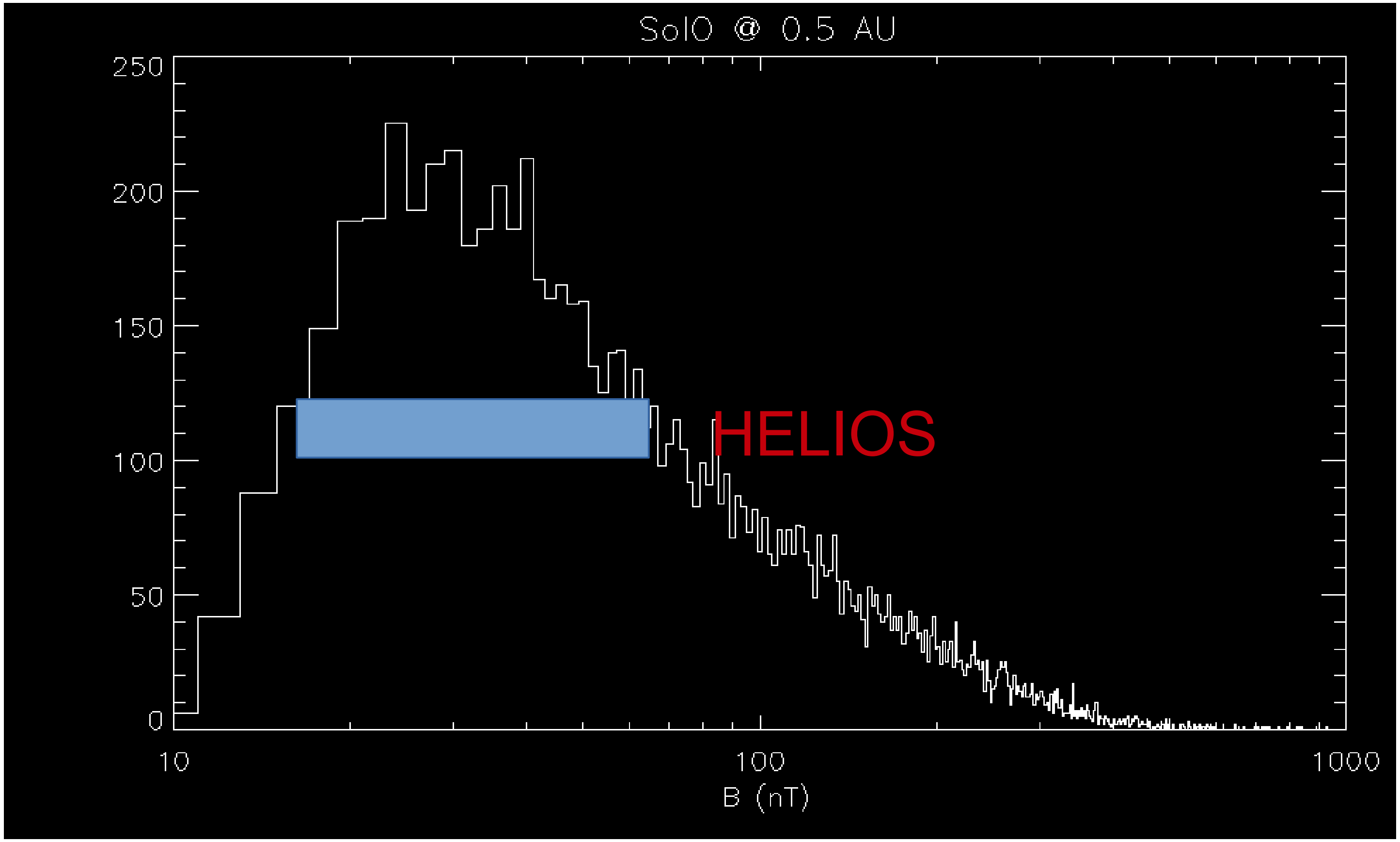
1. Find suitable datasets for near-Sun |B| field calculations applicable to as many of the available methods as possible --- **start with events already analyzed by the various team members** ----coordinate w/ the data and campaign WGs (yrs 1-2)

2 Assess the pros & cons of the various methods of near-Sun |B| determination &
extrapolation -- coordinate w/ the theory and modeling WGs (yrs 1-2)

3. Apply methods (existing or improved) to a sample of CMEs and determine near-Sun |B| → paper and list of events/data (yrs 2-3)

4. Extrapolate near-Sun |B| & orientation to 1 AU and compare
w/ in-situ measurements and MC fittings (Al-Haddad et al. 2013
for a benchmarking of available MC fitting methods)
→ paper and tables of pertinent data (yrs 3-4)

Predictions for SolO @ 0.5 AU



Predicted CME |B| for αB=-1.6 in the inner heliosphere

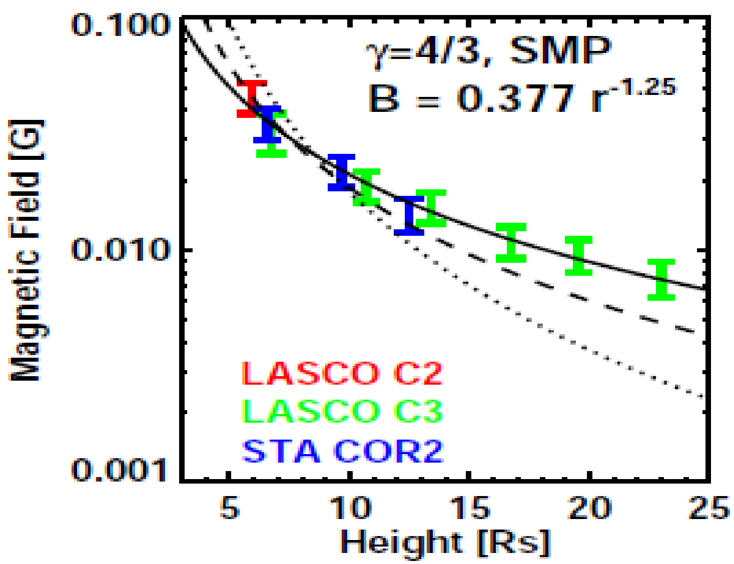
Models Recap

Model	BZ4CAST	H-CME	HELIO-XM	FiDO	Fried	FRED
shape	cylinder	cylinder/torus/spheromac	torus	torus	torus	torus
|B| near-Sun	N	Y	Y	N	N	Y
near-Sun deflections	Y	Y	N	Y	Y	N
IP propagation	radial	radial	radial	radial	radial	radial
|B| IP evolution	CCMC simulatior	Power-law	Force-balance	flux conservation	flux conservation	flux conservation
B vector	Y	N	Y	Y	Y	N

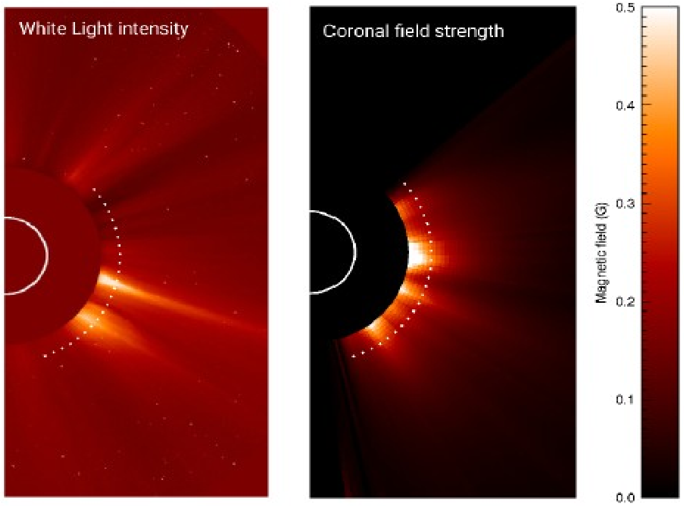
All models have pros and cons

CME-driven shocks

(1) shock stand-off distance from CME/shock WL/EUV observations & WL densities
(2) jump conditions & WL densities
→ *|B| in **sheath** & background*
(e.g., Vrsnak et al. 2002, Bemporad & Mancuso 2011; Zucca et al. 2014)

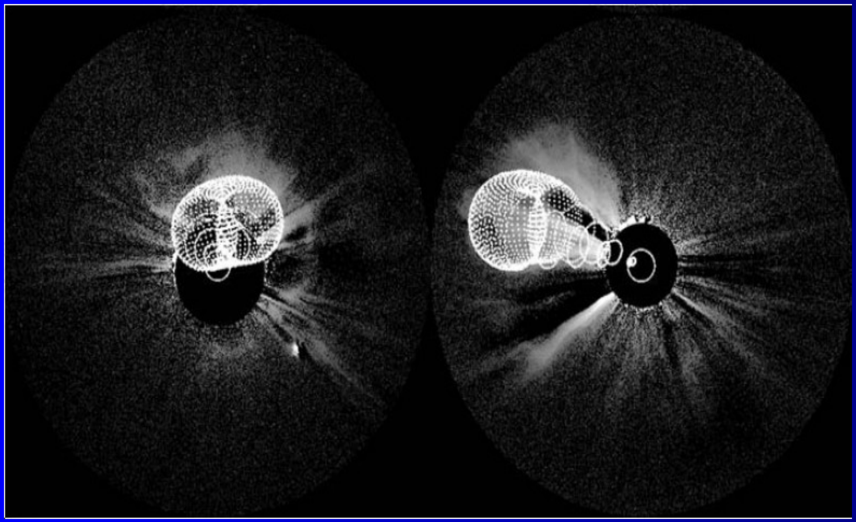


Gopalswamy & Yashiro 2011

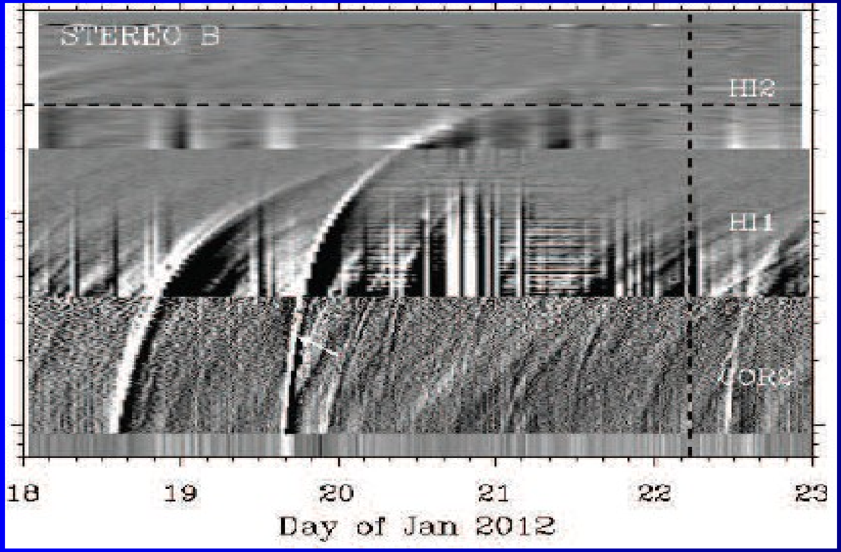


Bemporad et al. 2015

Extracting 3D info of CMES



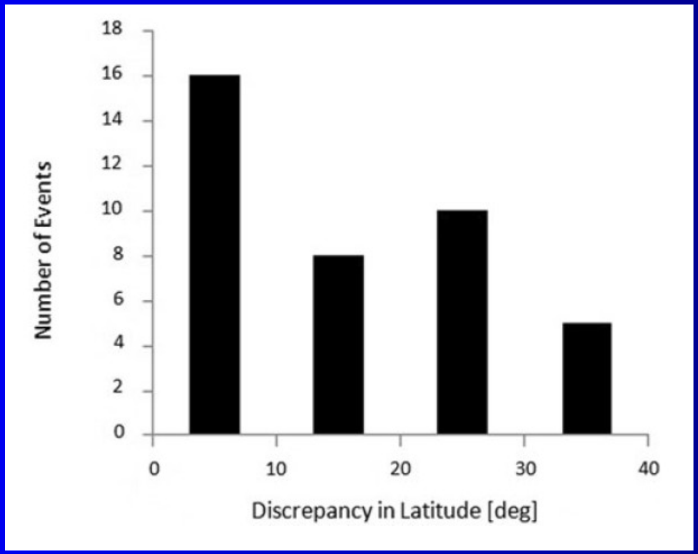
Forward geometrical modeling: GCS
Thernisien et al. (2009); Bosman et al. 2012 and many case-studies
fits the CME envelope & gives CME *height,size,direction,tilt*
not internal structure of CME
Extension to include CME deformations FRiED (Isavnin; 2017)



J-maps
assume CME shape (point, circle, ellipse) + radial propagation
→ CME speed & direction

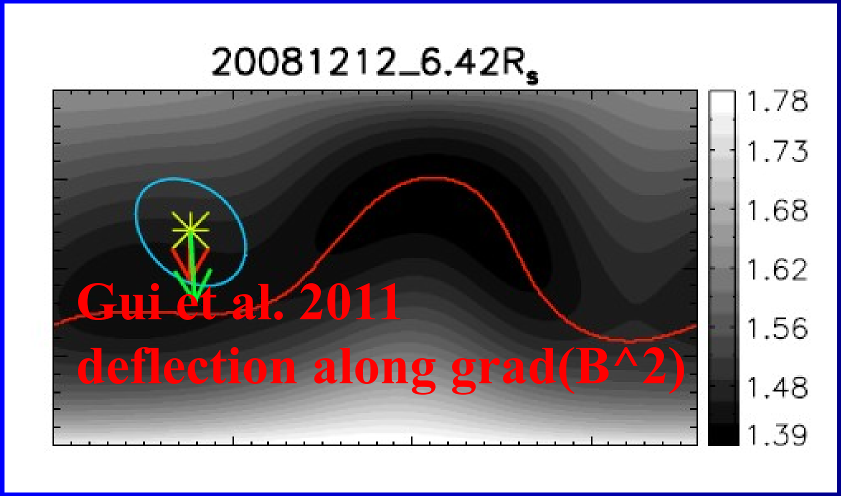
(e.g. Sheeley et al. 1999; Roulliard et al. 2011; Lugaz et al. 2010;
Mostl et al. 2011,2014; Rollet et al. 2011, 2016; Davies et al. 2012; Liu et al. 2013)

CME deflections close to the Sun (1.1-20 Rs)



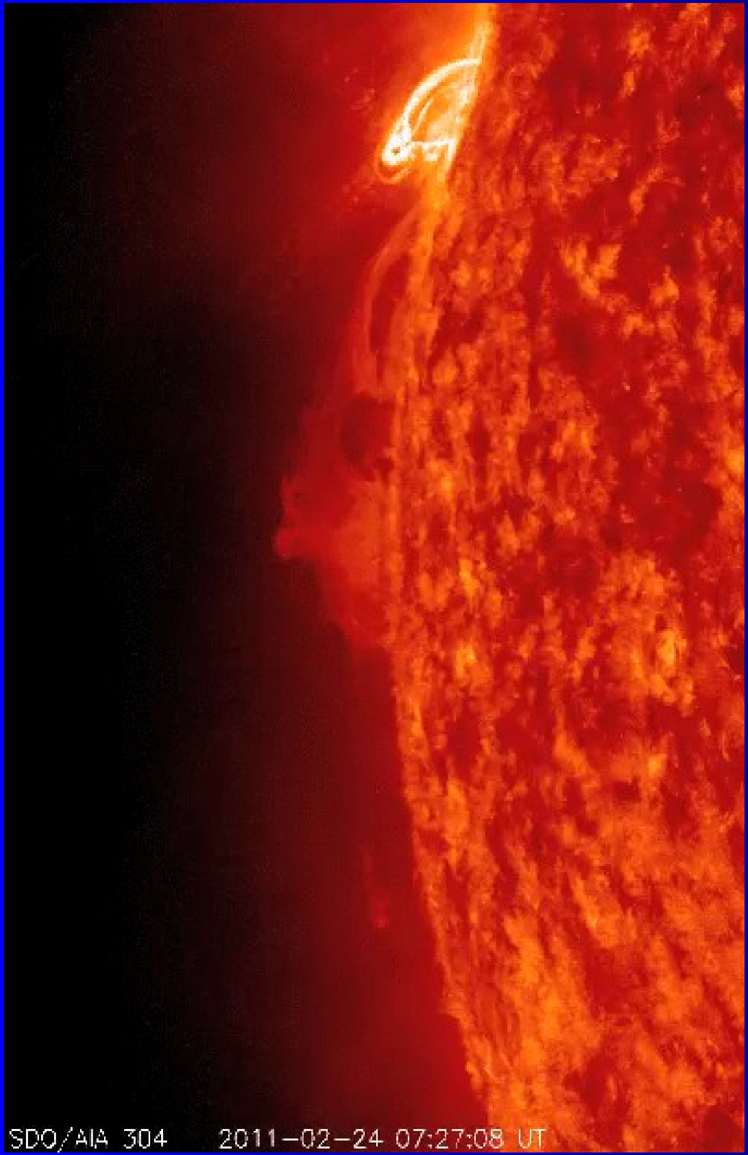
CME lat offset from SR

Bosman, Bothmer, Nistico 2012
39 CMEs in 2010
deflections~ [5,60] deg
from SR to 20 Rs
coverging towards equator

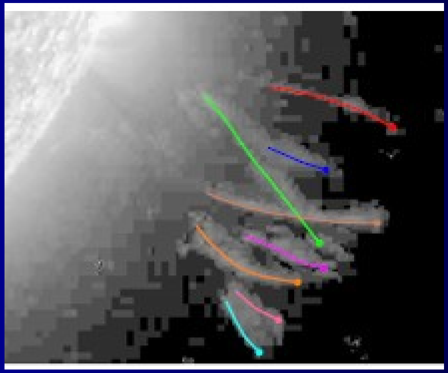


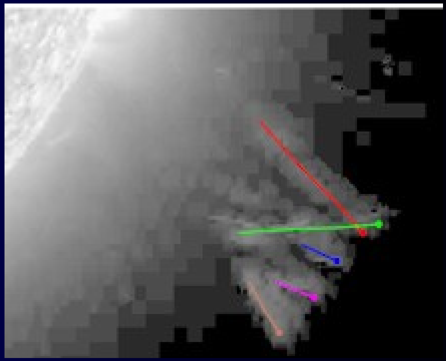
deflections → magnetic field gradients
(strong →weak)
Cremades, Bothmer, Tripathi 2006
Gopalswamy et al. 2010
Panasenco et al. 2011
Shen et al. 2011
Kay, Opher, Evans 2013

CME rotations close to Sun 1.1-5 Rs



3D reconstructions of prominence rotations

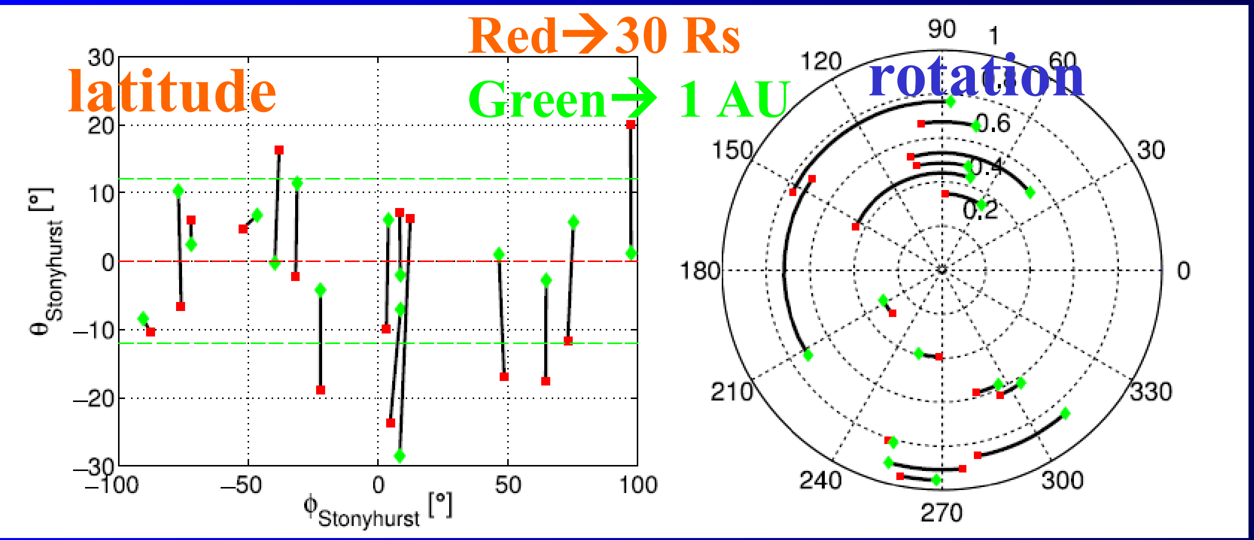




Thompson, Kliem, Torok 2012

rotations ~ [30,90] deg
Bemporad, Mierla, Tripathi 2011
Joshi &Srivastava 2011
Chifu et al. 2012
Su & van Ballegooijen 2012
Liewer, Panasenco, Hall, 2013
Filippov 2013
Bi et al., 2014

CME deflection & rotation from 30 Rs → 1 AU

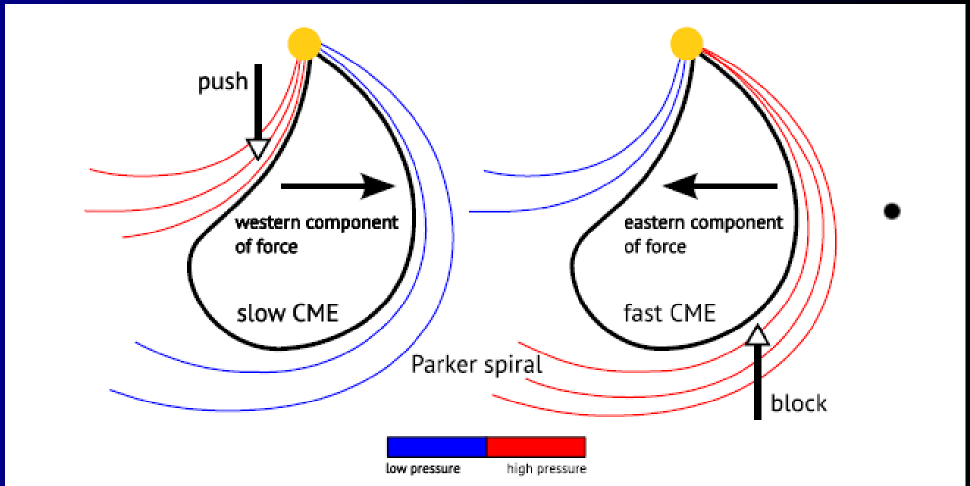


longitude

Isavnin, Vourlidas, Kilpua 2013,2014
15 CMEs 2008-2010
deflection ~ 2-30 deg
rotation ~ 2-80 deg
60% of variation in the first 30 Rs ;
Most magnetic deflection & rotation due within 10Rs
(Kay et al. 2015

Interaction of CME with Parker spiral
Wang et al. 2004

Weak CME b-field; how about solar-max CMEs?



Why bothering about CME magnetic fields ?

- **CMEs are powered by magnetic energy**

(e.g., Forbes 2000; Vourlidas et al. 2000; Carley et al. 2012; Emslie et al. 2012)

- **Near-Sun CME magnetic field can be used as a boundary condition of CME propagation models in the heliosphere**

(ENLIL: Odstrcil & Pizzo 2009; COIN-TVD: Shen et al. 2014; EUHFORIA: Poedts, Pomoell et al. 2016; SUSANOO-CME: Shiota, & Kataoka 2016)

- **Magnetic field determines the geoeffectiveness of CMEs**

(e.g., Burton et al. 1975; O'Brien and McPherron, 2000; Wu & Lepping 2002; Wang et al. 2003)

Future Work

1. Find suitable datasets for near-Sun |B| field calculations applicable to as many of the available methods as possible --- **start with events already analyzed by the various team members** - & populate list @ http://solar.gmu.edu/heliophysics/index.php/List_of_CMEs_for_WG5_Analysis ---> compare the predictions of various methods

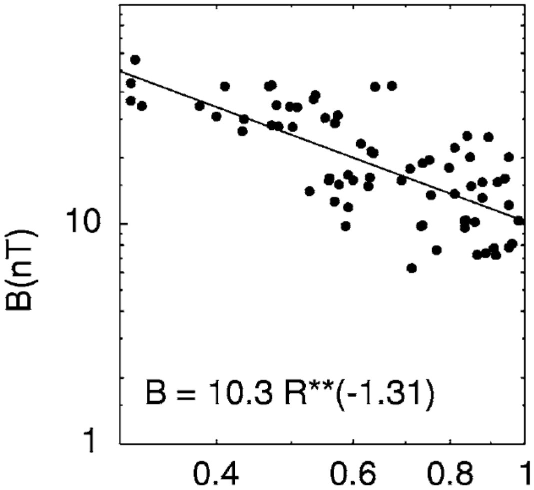
2. Perform parametric studies of the various methods of CME-ICME magnetic field determination ---> assess the full range of anticipated magnetic fields from the various methods

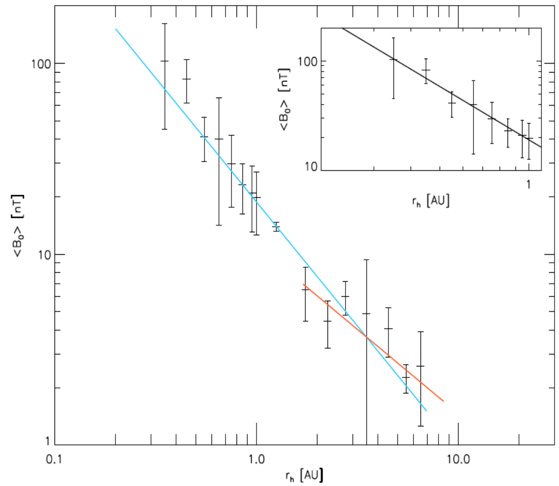
3 Cordinate with other WGs (data/modeling&theory/campaign) as well as with other teams on the topic (e.g., LWS, HELCATS)

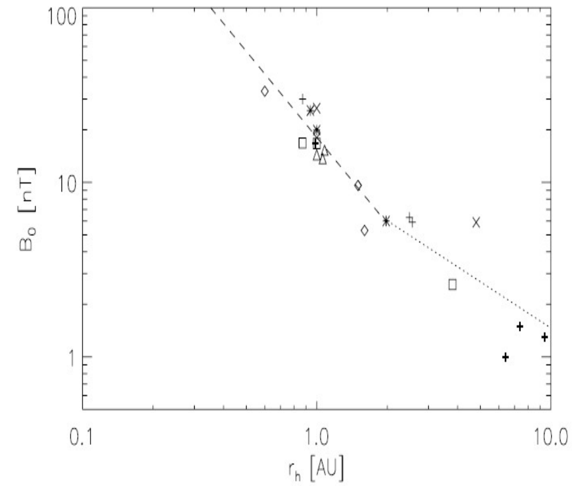
People who Expressed Interest

"Alissandrakis Costas, radio diagnostics",,,,,
"Bemporad Alessandro, shock-method",,,,,
"Bothmer Volker, CME-ICME propagation, MCs",,,,,
"Dasso Sergio, theory/modeling of CME expansion and evolution",,,,,
"Georgoulis Manolis, helicity method",,,,,
"Hess Phill, flux-rope method",,,,,
"Isavnin Alexei, CME rotations/deflections mod+obs, MC-fitting",,,,,
"Kay Christina, CME rotations/deflections modeling",,,,,
"Kilpua Emilia, CME-ICME propagation",,,,,
"Maia Dalmiro, radio observations",,,,,
"Mancuso Salvatore, radio diagnostics",,,,,
"Mierla Marilena,",,"CME-ICME evolution ",,,
"Moestl Christian, MC fitting CME-ICME evolution",,,,,
"Nindos Alexander helicity method, radio diagnostics",,,,,
"Opher Merav, CME rotations/deflections modeling",,,,,
"Patsourakos Spiros, helicity method",,,,,
"Riley Pete, ","CME-ICME evolution, POC with LWS team on Bs",,,,
"Rodriguez Luciano",,"CME-ICME evolution   Mcs",,,
"Rouillard Alexis, flux-rope model",,,,,
"Savani Neel, CME deformations, shock method",,,,,
"Shen Chenglong, MHD modeling of CME rotation/expansion ",,,,,
"Shen Fang , MHD modeling of CME rotation/expansion ",,,," POC with WG3",
"Temmer Manuela, CME-ICME evolution, reconnected flux",,,,"x POC with WG6",
"Veronig Astrid, CME-ICME evolution, reconnected flux",,,,,
"Vrsnak Bojan, theory of flux-rope model and radio diagnostics",,,,,"POC with WG2"
"Wang Yuming, MHD modeling of CME rotation/expansion ",,,,,
"Webb David, POC ",,"with WG4",,,
"Zhang Jie, flux-rope method",,", POC with WG1",,,
"Zhukov Andrei",,"CME-ICME evolution",,,

Inner heliospheric evolution of ICME-MC |B|: Helios 1/2 results







Bothmer and Schwenn 46 MCs (1998); αB ~ -1.73
Forsyth et al. (2006) 103 ICMEs; αB ~ -1.31
Leitner et al. (2007) 46 MCs; αB ~ -1.64

Describe the B evolution of an <ICME>
Few alignement studies (Leitner et al. 2007)
Not comprehensive remote sensing observations

Breakdown of the problem

We need to predict Bs at 1 AU →
magnitude & orientation of B at 1 AU

The problem consists of 4 basic steps:

(1) ***Deduce near-Sun |B| of CMEs***

(2) Deduce near-Sun orientations of CMEs

(3) **Extrapolate *near-Sun |B| to 1 AU***

(4) Extrapolate **near-Sun orientation to 1 AU**

Forecasting of Bn using Pattern Recognition (Riley et al. 2017)

Use simple pattern recognition applied to OMNI 1-hour cadence data covering 10 years to predict the state of solar wind Δt (6 hours – few weeks) into the future

@ time t shift backwards by Δt & compare with a sliding window of width Δt spanning all the data-base

Find 50 best-matching intervals & use their corresponding next Δt