An Introduction to the VarSITI/ISEST-MinMax24 WG5

The Bs challenge Group

http://solar.gmu.edu/heliophysics/index.php/Working_Group_5

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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.

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**

Near-Sun CME |B|

NLFF extrapolations (e.g. Wiegelmann et al. 2008) : low corona & capture equilbrium/near-equilbrium states (CMEs at least close to Sun could have significant JxB e.g., Subramanian et al. 2014)

Applicable diagnostics …

radio observations (gyrosynchrotron & Faraday rotation)

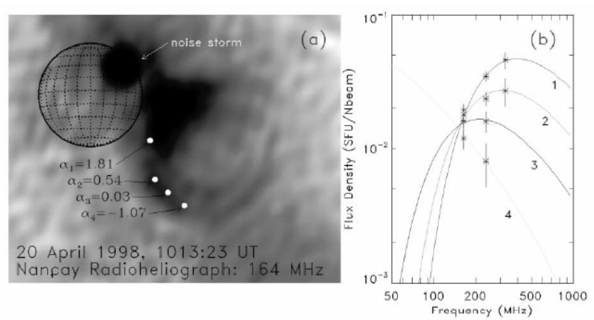
CME-driven shocks (sheath) → WL imaging of CME/shock

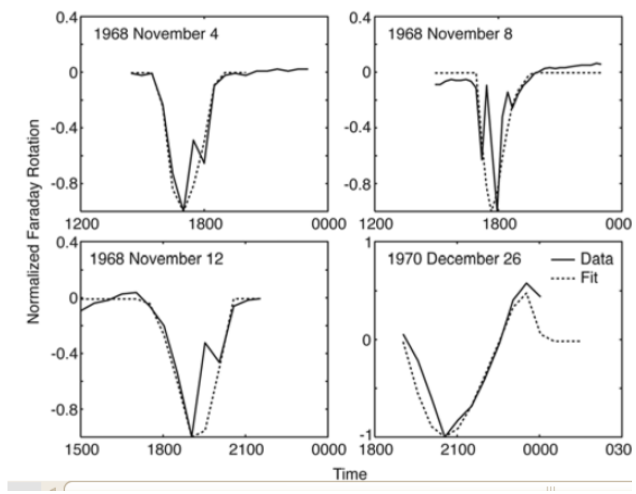
flux-rope model → h-t of CME flux rope model

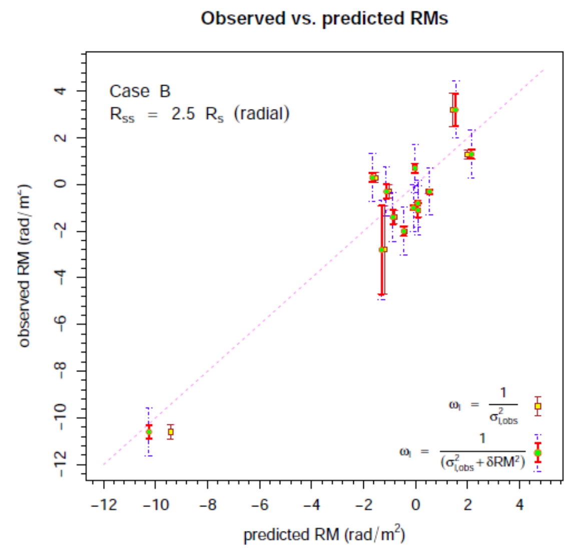
helicity method → inner corona helicity & geometrical CME parameters

Near-Sun CME |B|:radio observations

Radio obs of gyrosynchrotron emission and Faraday rotation + (WL/EUV to get column density obs) → |B|



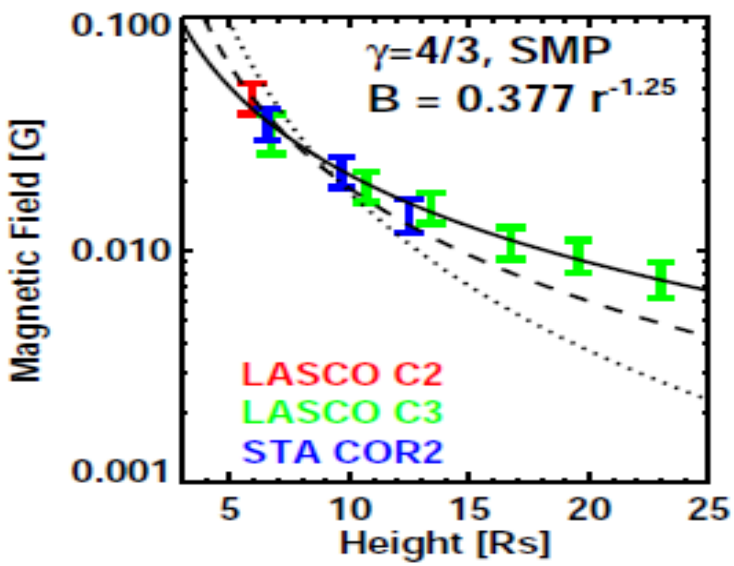




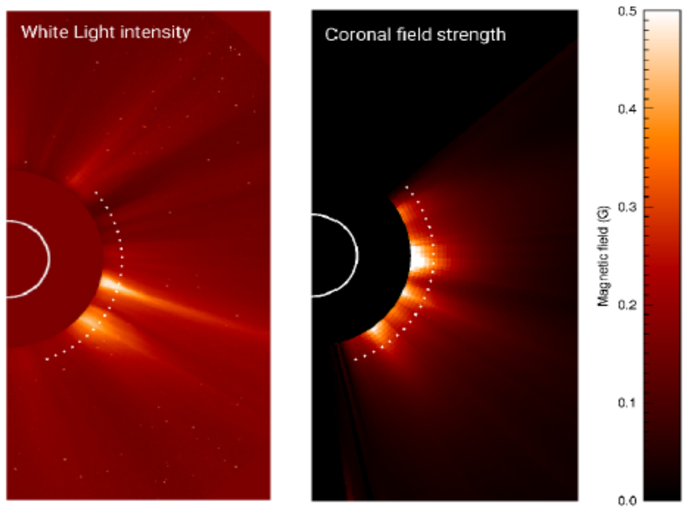
SCANT observations for both CMEs and the background corona: e.g., Bastian et al. 2001, Jensen & Russel 2008, Mancuso & Garzelli 2013; Spangler et al. 2013;Tun & Vourlidas 2013;)

Near-Sun |B|: CME-driven shocks

(1) shock stand-off distance from CME/shock WL 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)

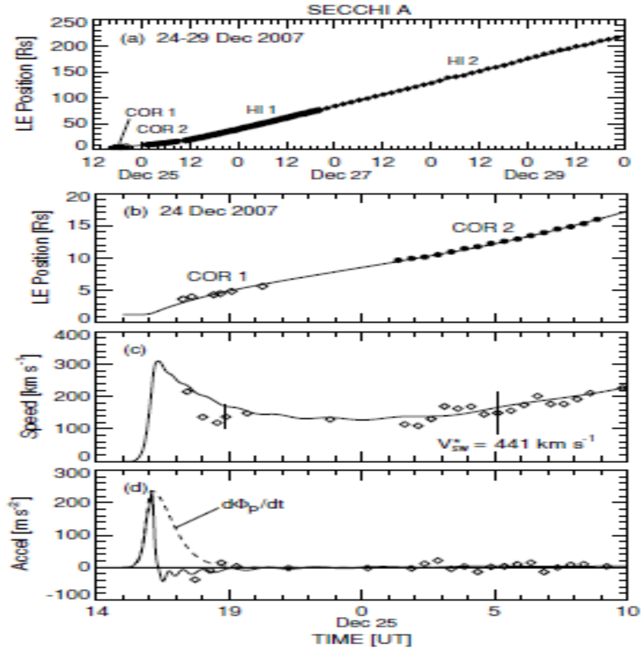


Gopalswamy & Yashiro 2011



Bemporad et al. 2015

Near-Sun CME |B|:flux-rope method



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

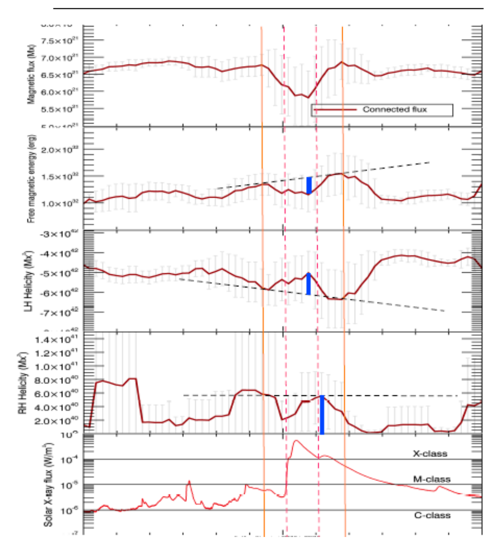
Use observed h-t of a CME to determine its poloidal flux injection profile to match the flux rope kinematics (hoop force)
→ |B| & Bx,By,Bz at all distances

Get poloidal flux injection profile directly from photospheric/low corona observations (e.g. Qiu et al. 2007; Mostl et al. 2009)

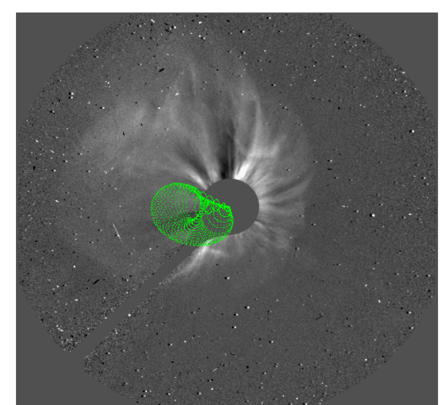
Near-Sun CME b-field:helicity method

|B| for magnetic flux-ropes
=f(magnetic helicity Hm, geometrical params (R, L); Dasso et al. 2003

Hm ← calculation @ photosphere & low corona from photospheric magnetic/flow obs & extrapolations (e.g., Pariat et al. 2005; Georgoulis et al. 2012; Moraitis et al. 2014)



R&L ← geometrical fitting of CMEs with the GCS model of Thernisien et al. (2011)



First application in Patsourakos et al. (2015)

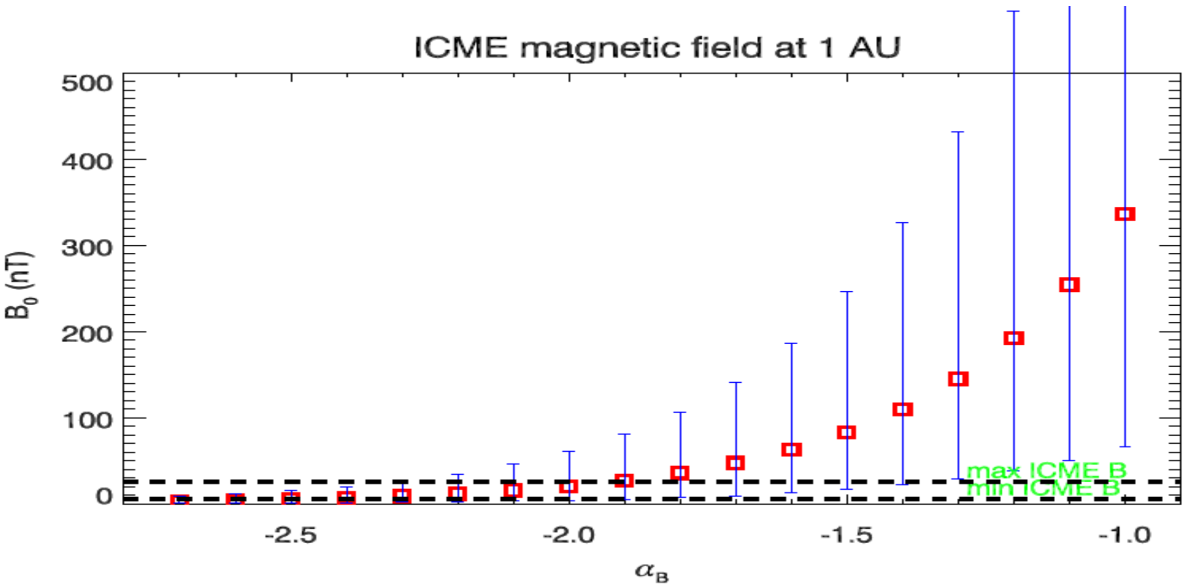
Extrapolation of CME |B| to 1 AU I

(1) Extrapolation using a power-law of the radial distance r

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

α_B from Demoulin & Dasso 2009;
Bothmer & Schwenn 1998; Leitner et al. 2007 etc

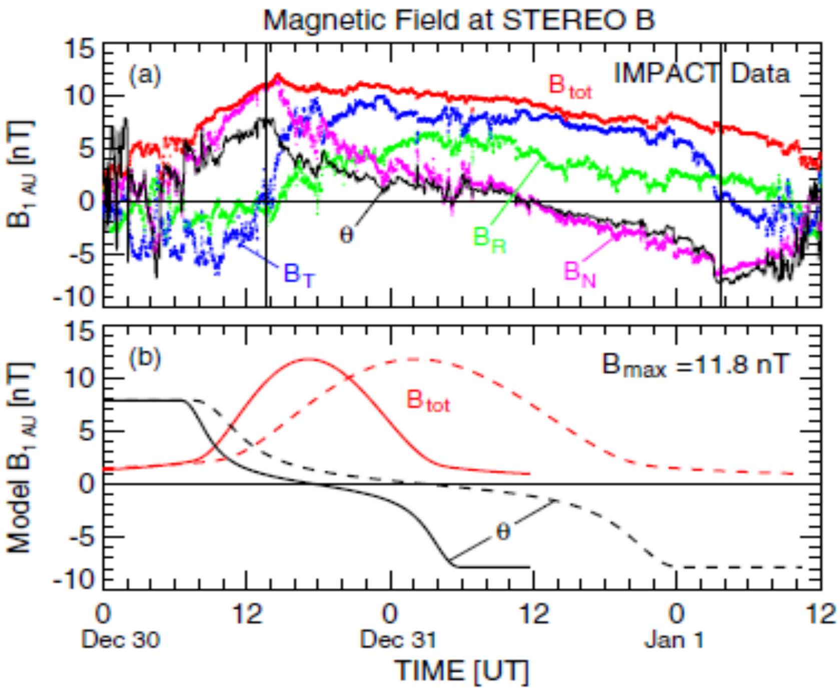
compilation of
of observations & models → [-2.7, -1.0]



Patsourakos et al. 2015

Extrapolation of CME |B| to 1 AU II

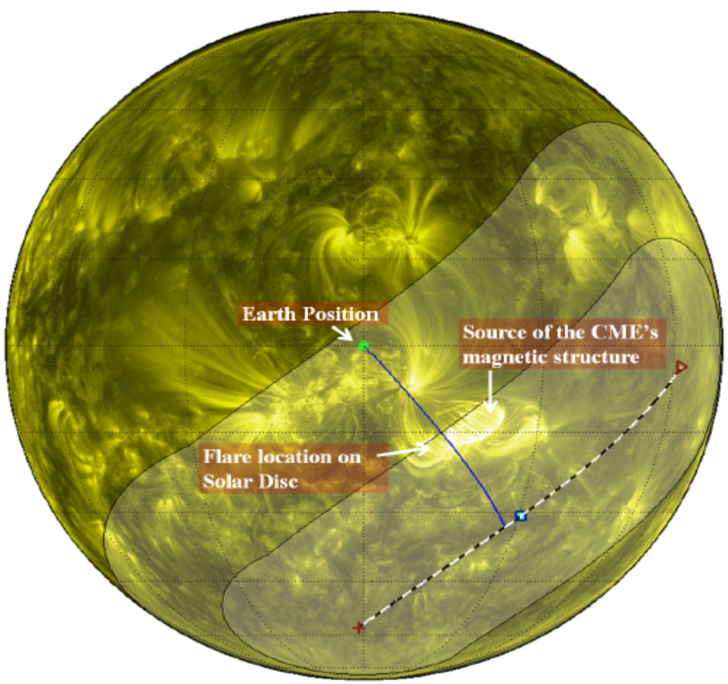
(2) Use of force equation of flux-rope model to reproduce its h-t (e.g., Kunkel & Chen 2010)

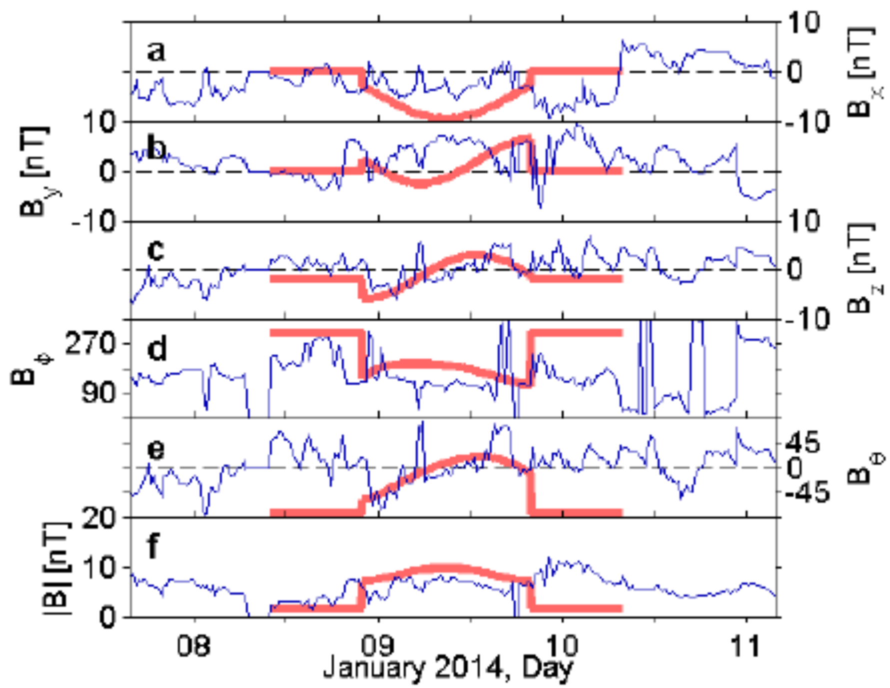


Possible impact of CME flattening (e.g., Savani et al. 2010) & erosion (Lavraud et al. 2014) in the deduced |B| profiles?

Extrapolate CME orientation to 1 AU I

(1) Use GCS fittings & Hm sign at Sun & determine volume of influence of the CME-ICME in the heliosphere---> orientation of axial field & impact parameter (Bvec) @ 1 AU (Savani et al. 2015)

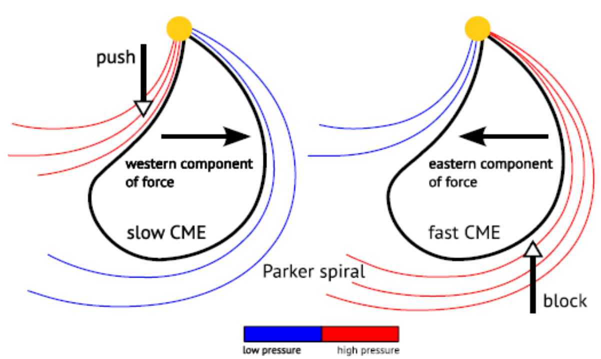


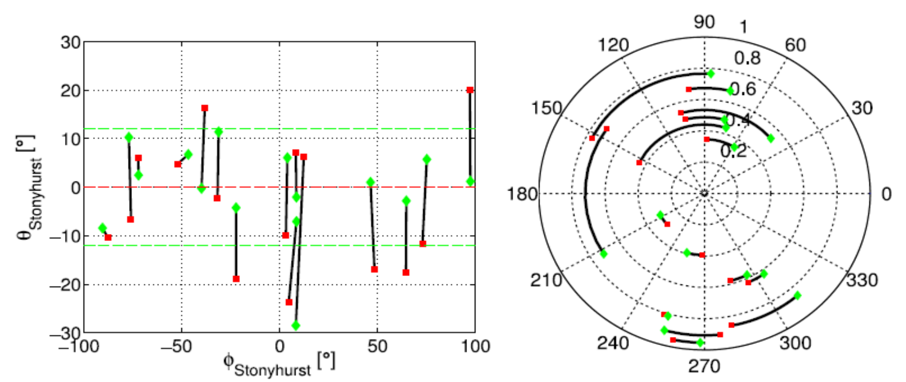


Extrapolate CME orientation to 1 AU II

(2) CME rotations ← kinematic interactions with the Parker spiral
(Wang et al. 2004; Isavnin et al. 2014, Wang et al. 2014)
& magnetic background (Shen et al. 2011; Kay et al. 2013)

Semi-analytical models & background wind & b-field required
for this task as per the studies above





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 (e.g., by K. Marubashi, N. Savani**----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)

VB: We should also establish a brief list of fundamental questions