Parametric Study of a Helicity-based Method to Infer the Near-Sun Magnetic Field of Coronal Mass Ejections

Spiros Patsourakos, University of Ioannina, Greece
&
Manolis K. Georgoulis, RCAAM, Academy of Athens, Greece

HELLENIC NATIONAL SPACE WEATHER RESEARCH NETWORK
Thalis Project

European Union
European Social Fund
OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION, LIFELONG LEARNING AND RELIGIOUS AFFAIRS
MANAGING AUTHORITY
Co-financed by Greece and the European Union
NSRF 2007-2013
programme for development
EUROPEAN SOCIAL FUND

SEVENTH FRAMEWORK PROGRAMME

Motivation

➔ The magnetic field is a crucial parameter for the dynamics, structure and the geoeffectiveness of CMEs

➔ Few and difficult to make B_{CME} observations in the the corona based on radio (e.g., Bastian et al. 2001; Jensen & Russel 2008; Tun & Vourlidas 2013)

➔ Need methods of B_{CME} estimation easy to implement

Outline

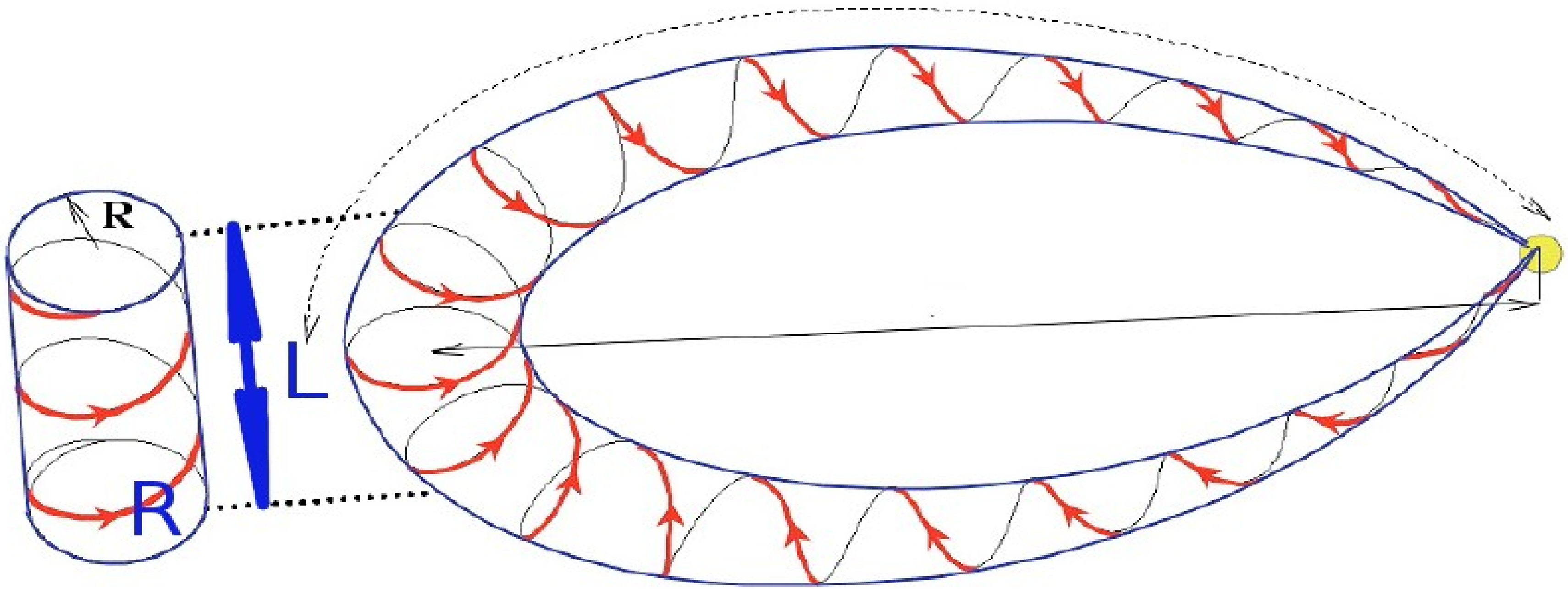
- ➔ Present a novel method of BCME estimation in the corona based on the conservation of the magnetic helicity

- ➔ Input: photospheric magnetograms & multi-viewpoint coronagraph images

- ➔ Parametric study of the method & extrapolation of coronal BCME to 1 AU

- ➔ Compare with MC BCME observations @ 1 AU

Cylindrical approximation of a flux rope



Demoulin & Dasso 2013

B-field for cylindrical linear force-free flux-rope model

$$B_r = 0,\ B_\phi = \sigma_H B_0 J_1(\alpha r),\ B_z = B_0 J_0(\alpha r)$$

Lundquist 1950

r=0 $\rightarrow$ purely axial b-field

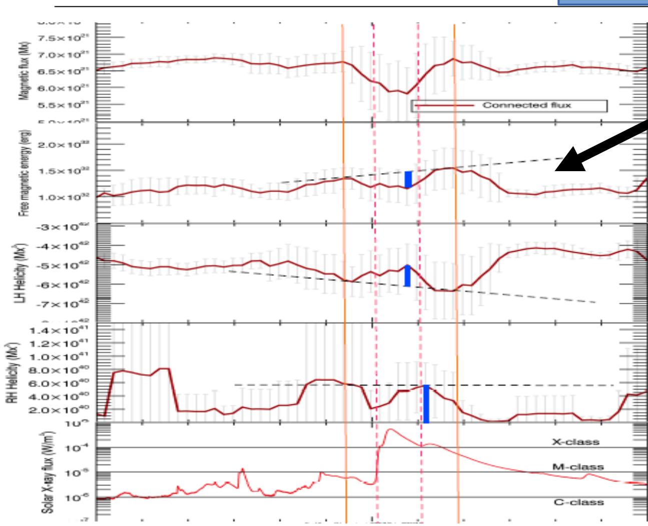
$$\alpha R = 2.405$$ → purely poloidal field at FR edge

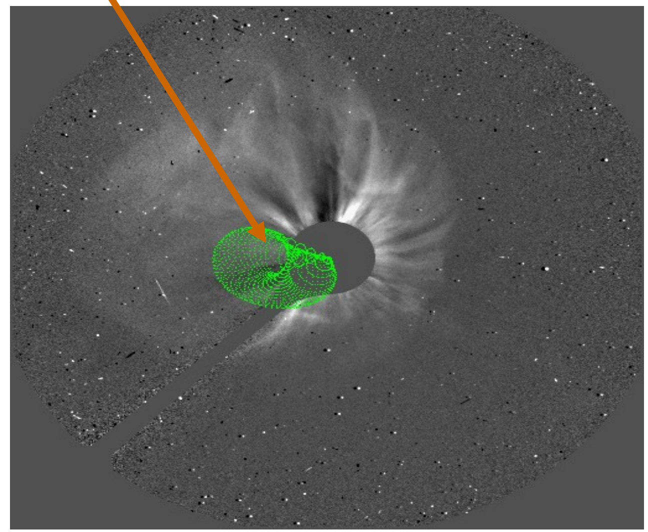
$$H_m = \frac{4\pi {B_0}^2 L}{\alpha} \int_0^R {J_1}^2(\alpha r)\, dr$$

Dasso et al. 2003

Constraining BCME from observations

B=B(Hm, R, L)





Hm from photospheric magnetograms of the source region (e.g., Nindos et al. 2003; Georgoulis et al. 2012 Moraitis et al. 2013)

GCS model of Thernisien et al. (2009) applied to coronagraph images

helicity conserved Berger (1984)

Extrapolating BCME from the corona to 1 AU

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

α_B from various models & observations [-2.7, -1.0]
e.g., reviews of Demoulin&Dasso (2013);
Mancuso & Gartzelli (2013)

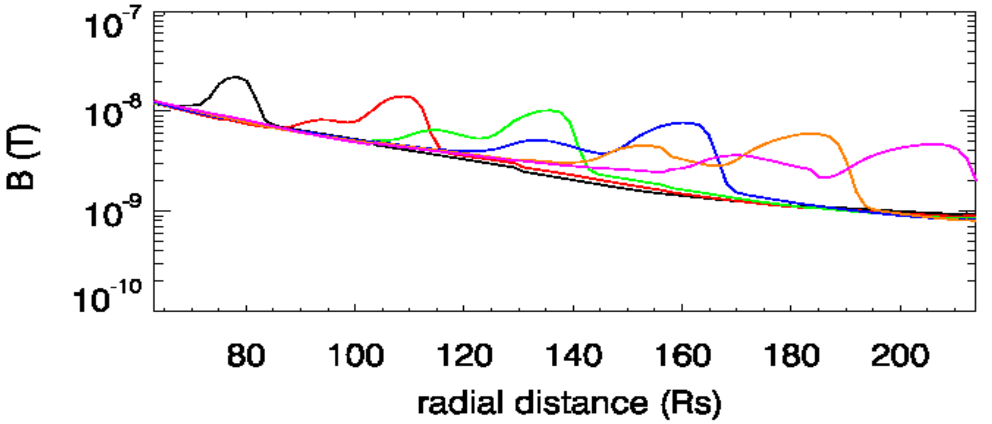
Use ELNIL simulations to determine α_B

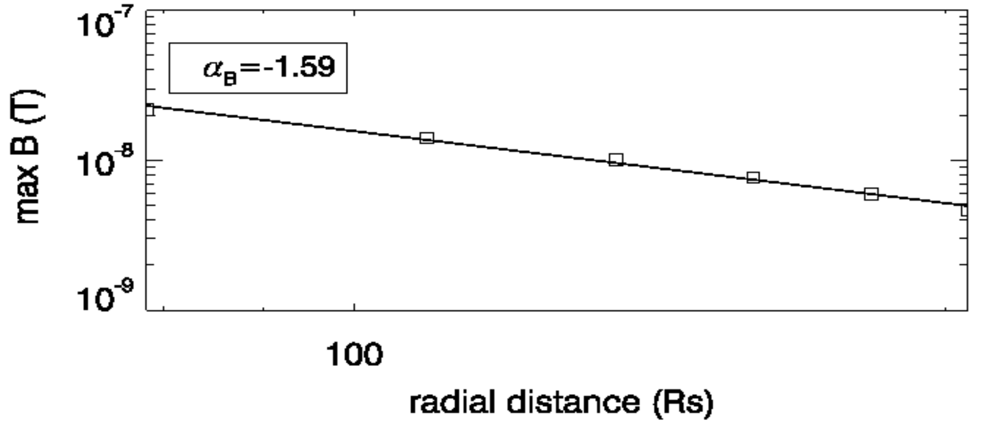
➔ Use the ELNIL (Odstricil&Pizzo 1999) MHD code under NASA's CCMC to simulate & track heliospheric disturbances from 20 Rs – 1 AU

➔ Run a grid of 9 simulations varying the initial speed, pressure enhancement

➔ Track the disturbance & calculate α_B

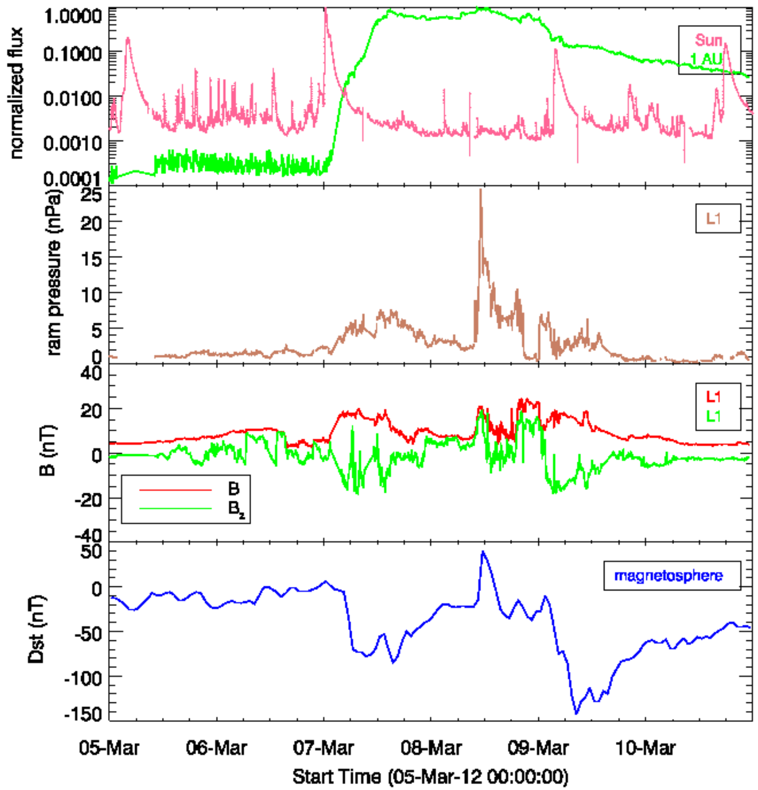
Example: CME @ 2000 km/s

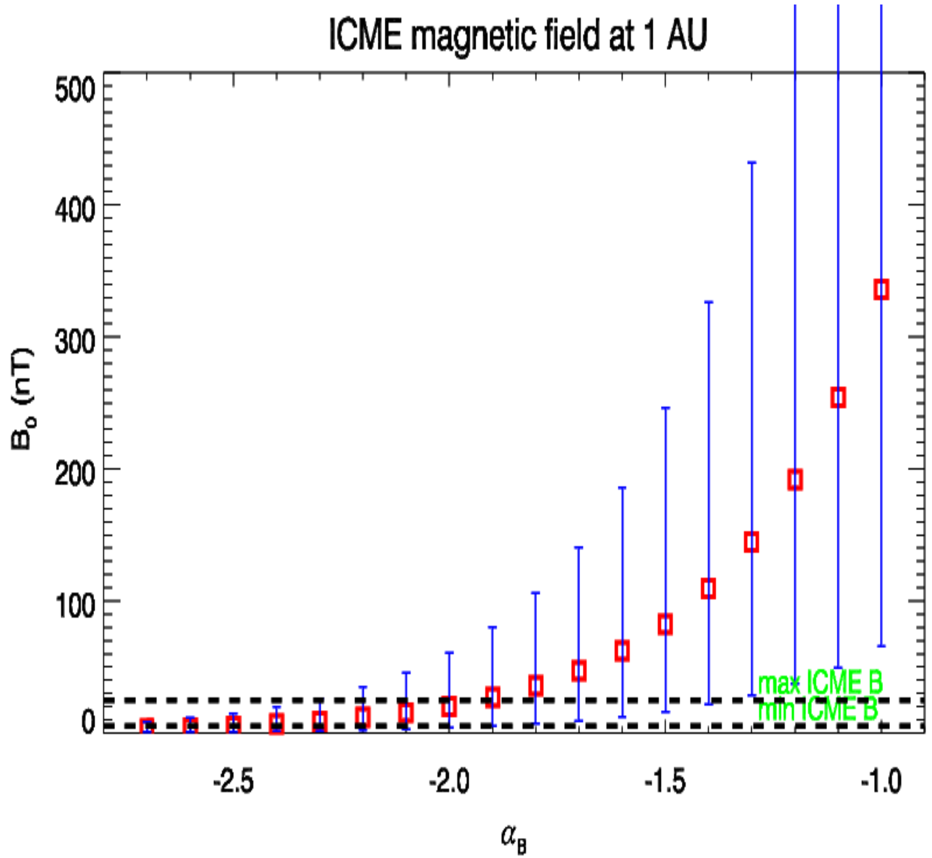




α_B --> [-1.8, -1.2] $\langle \alpha_B \rangle = -1.5$

Application to a case study





Patsourakos et al. (2015)

Parametric study

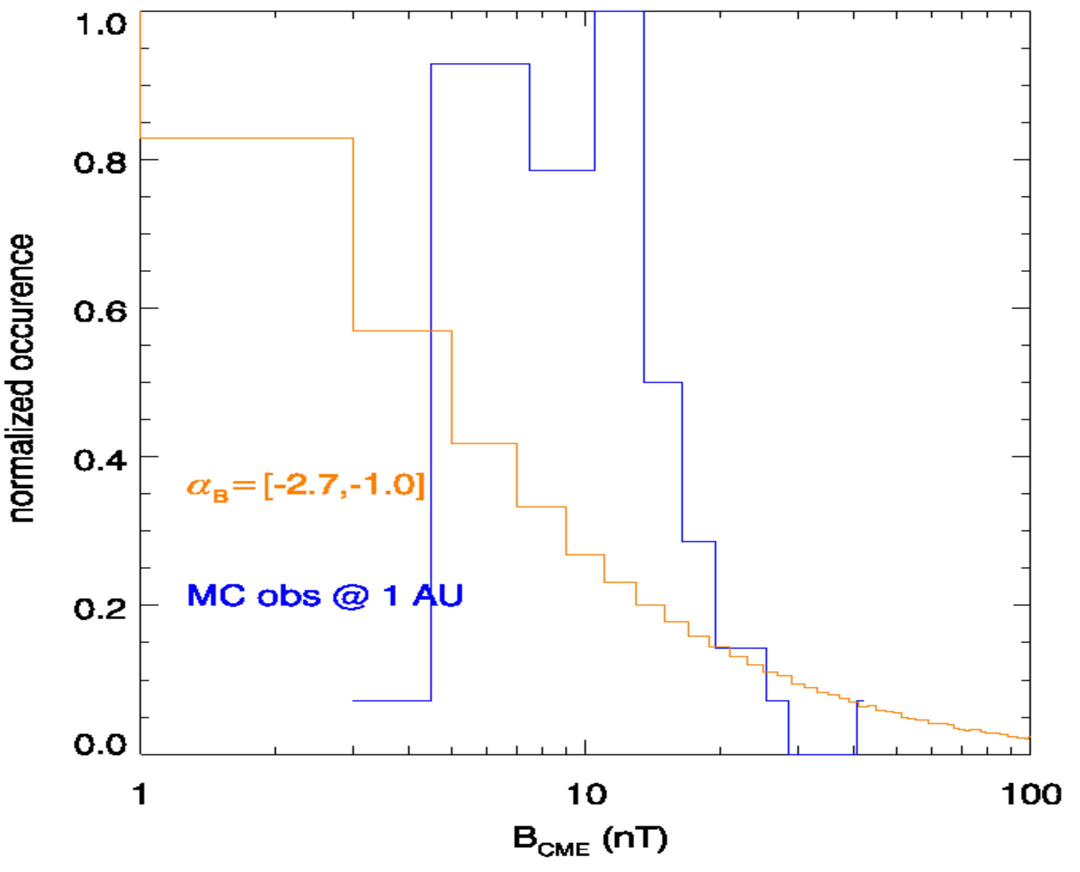
- ➔ Pick up 10000 random samples of R&L from the distribution of the STEREO CME observations (Thernisien et al. 2009; Bosman et al. 2012) (N=65)

- ➔ Pick up 10000 random samples from the Hm distribution in ARs (Tziotziou et al. 2013) (N=162)

- ➔ Calculate B_{CME} @ 10 Rs for 10000 synthetic CMEs

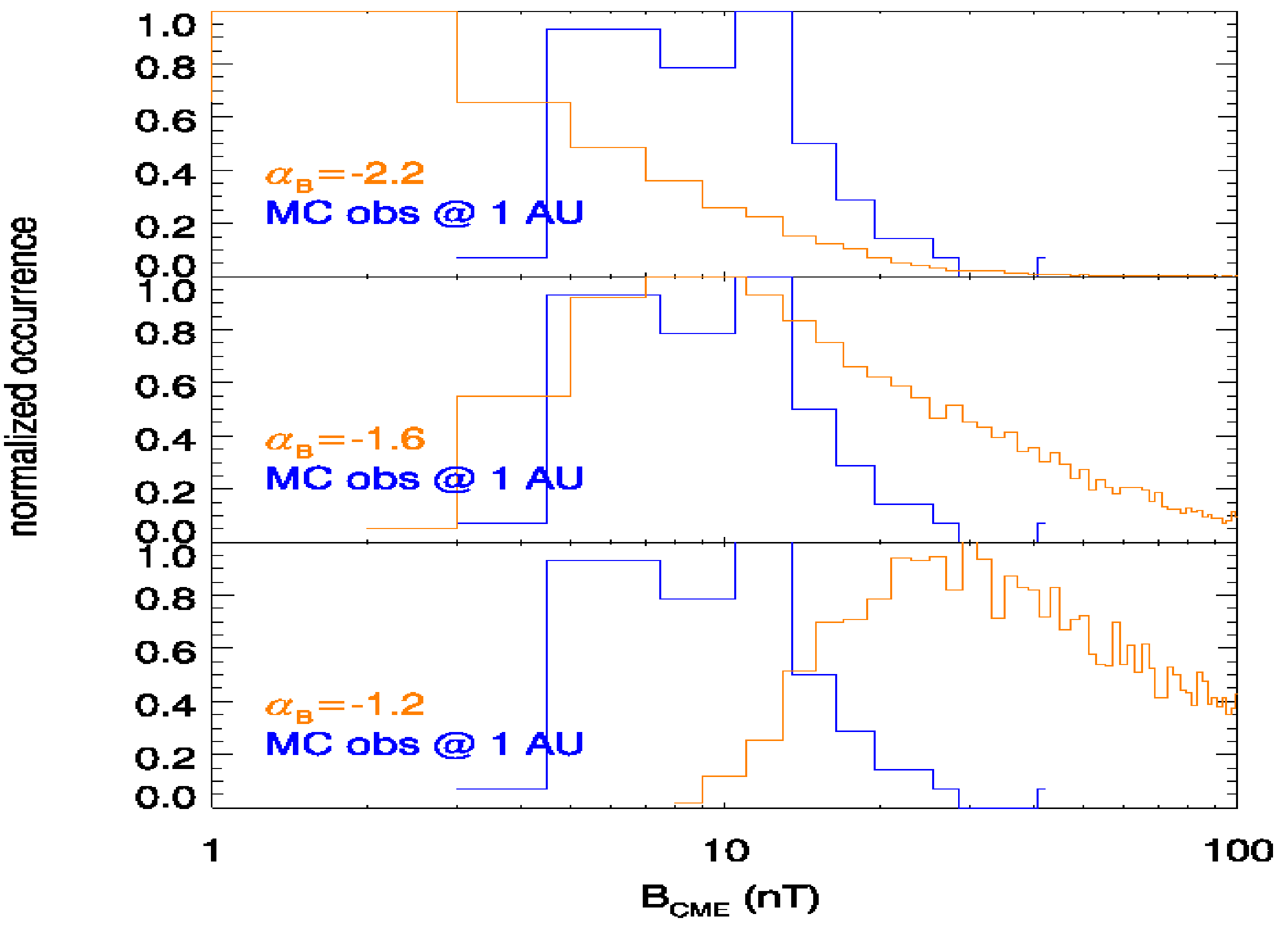
- ➔ Extrapolate B_{CME} to 1 AU & compare with MC observations (Lynch et al. 2003; Lepping et al. 2006) (N=138)

Extrapolated BCME @ 1 AU I



The full range of αB does not fit the distribution of the MC B's

Extrapolated BCME @ 1 AU II



too steep or too shallow radial fall-offs don't work

Conclusions & Outlook

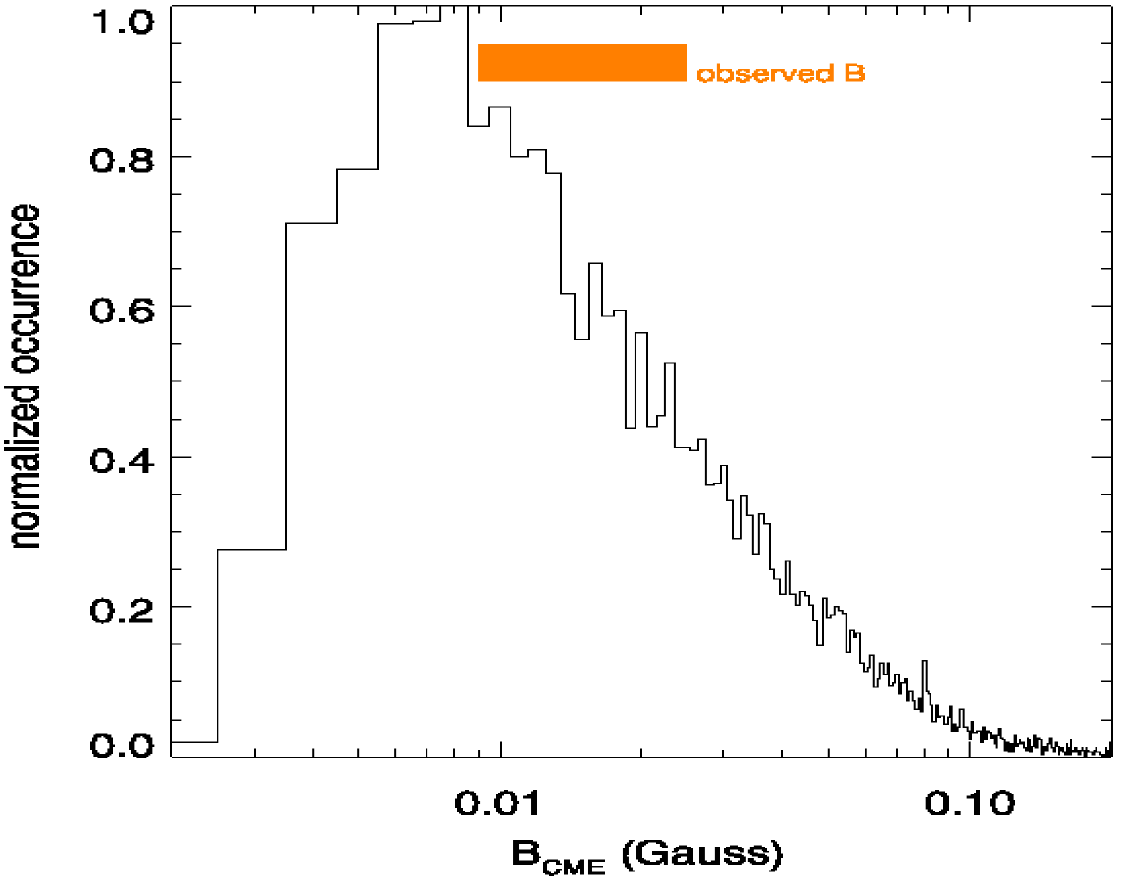
- ➔ Easy to implement method for routine estimation of near-Sun CME b-field: set of magnetograms & multi-viewpoint coronagraph images

- ➔ Parametric study of the method based on statistics of its input parameters

- ➔ **αB~ -1.6** extrapolated BCME @ 1 AU ballpark of MC B's

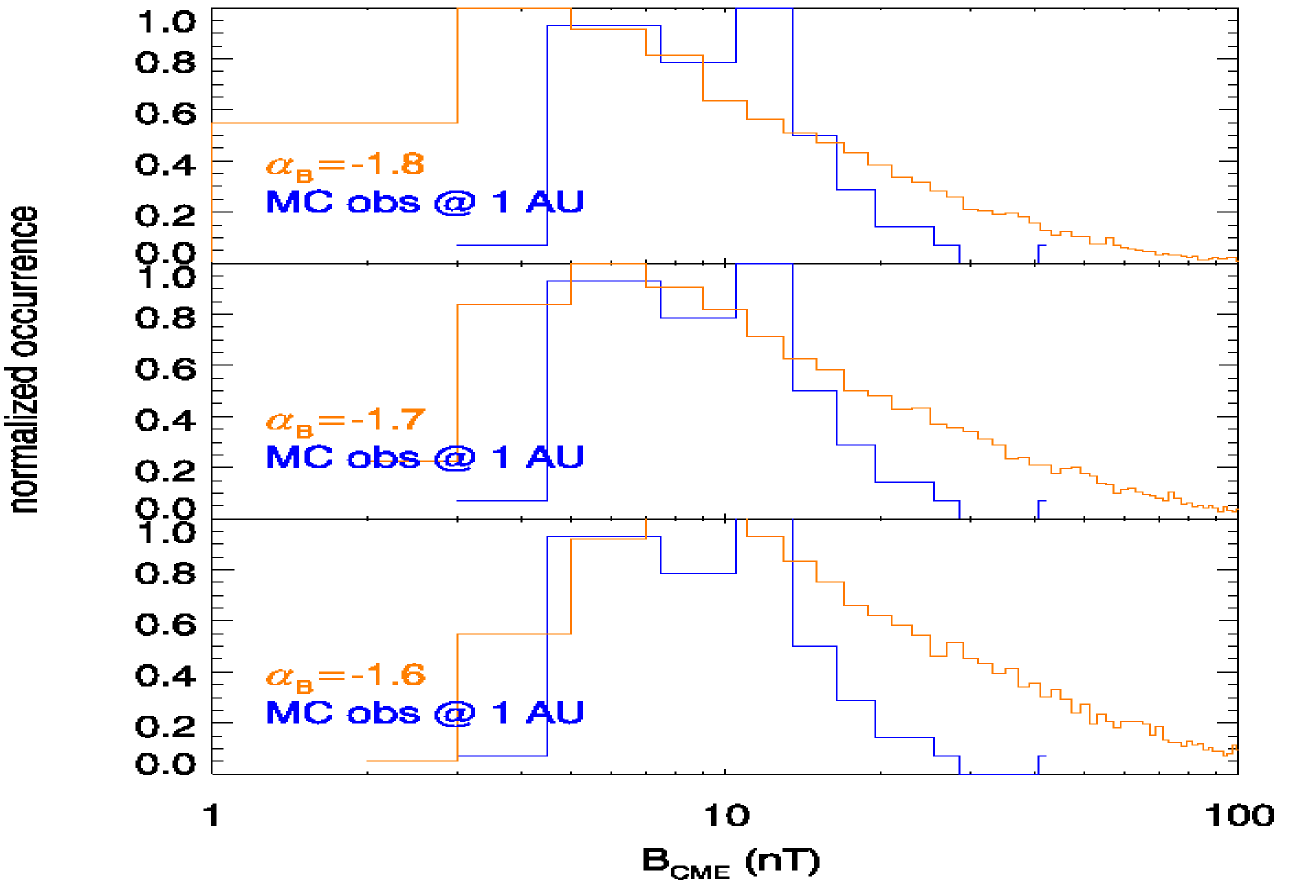
- ➔ *Non-force free-models, MHD modeling curvature,multiple power-laws of B, erosion ...*

Near-Sun BCME (10 Rs)



>= B-field of the quiet corona

Extrapolated BCME @ 1 AU III



ballpark of B of MC for αB ~ -1.6