Geometric and magnetic properties of coronal flux ropes associated with CMEs leading to geomagnetic storms

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Abstract. We have studied three Interplanetary Coronal Mass Ejections (ICMEs) having clear signatures of magnetic cloud (MC) arrival at 1 AU and their associated solar sources during 2011 to 2013. Comparing the axial magnetic field strength (B_0) of the near-Sun coronal flux-ropes with that of the MC at 1 AU, we have found that the average inferred value of B_0 at 1 AU assuming the self-similar expansion of the flux-rope is two times smaller than the value of B_0 obtained from the results of MC fitting. Furthermore, by comparing the initial orientation of the flux-rope near the Sun and its final orientation at 1 AU we have found that the three CMEs exhibited more than $80°$ rotation during its propagation through the interplanetary medium. Our study suggests that although the near-Sun magnetic properties of coronal flux-ropes can be used to infer the field strength of the associated MC at 1 AU, it is difficult to estimate the final orientation of the MC axis in order to predict the geo-effectiveness of the ICMEs.

Keywords. Flares, coronal mass ejections (CMEs), magnetic fields.

1. Introduction

Predicting the strength and orientation of the magnetic field associated with the interplanetary coronal mass ejections (ICMEs) is one of the key challenges in space weather physics. Study of both the remote-sensing and in-situ data are required in order to infer the magnetic properties of ICMEs in advance. Recent studies reveal that the magnetic properties of near-Sun coronal flux ropes are well-correlated with that of the ICMEs at 1 AU (Gopalswamy *et al.*, 2017). In this work, we aimed to study the geometric and magnetic properties of near-Sun coronal flux-ropes and that of ICMEs in order to understand the geo-effectiveness of the associated magnetic clouds.

Table 1. Comparison of the magnetic properties of near-Sun coronal flux ropes with that of the MCs at 1 AU

| CME in LASCO dd/mm/yy	Tilt angle on solar disk	Tilt angle from GCS fitting	B_0 [mG] at 10 R_s		ϕ_p at 10 R_s [$\times 10^{21}$ Mx]		ϕ_t at 10 R_s [$\times 10^{21}$ Mx]		Tilt angle of the MC	B_0 [nT] at 1 AU	ϕ_p [$\times 10^{21}$ Mx] at 1 AU	ϕ_t [$\times 10^{21}$ Mx] at 1 AU	Helicity [Mx^2] of the MC
			PEA	FRA	PEA	FRA	PEA	FRA					
01/19/2012 15:12 UT	$74°$	$60°$	46.9	32.2	9.4	6.4	12.8	8.8	$-40°$	9	0.9	0.1	9×10^{40}
07/12/2012 16:48 UT	$45°$	$52°$	130	48	1.4	5.3	0.6	2.2	$-62°$	43	29.6	32.1	9.5×10^{44}
03/15/2013 07:12 UT	$53°$	$70°$	40	–	3.8	–	1.9	–	$-12°$	13	0.6	0.3	2×10^{41}

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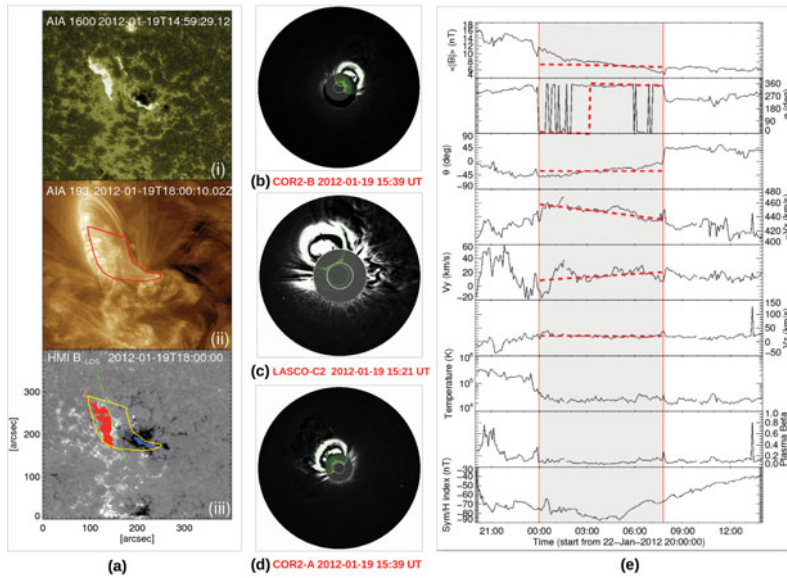
Figure 1. Panel [a](i):Flare ribbons in AIA 1600 Å image for the M3.2-class flare on 19th January 2012.The red boundary line in Panel [a](ii) marks the PEA in AIA 193 Å image. Panel [a](iii): HMI line-of-sight magnetic field. The red and blue regions depict the cumulative flare ribbon area overlying the positive and negative magnetic field respectively. The yellow line mark the region underlying the PEA shown in Panel [a](ii) and the green dotted line denotes the possible orientation of the flux rope. Panels [b]-[d]: The CME morphology observed from COR2-B, LASCO C2, and COR2-A, respectively. The overplotted green dots represent the bestfitted wireframe of the magnetic flux rope in the GCS model. Panel (e): Magnetic cloud fitting for the associated ICME.

2. Summary and Discussion

Estimating the reconnection flux underlying the post eruptive arcades (PEA) and the cumulative flare ribbon area (FRA)(Figure 1), we have calculated the near-Sun properties of the coronal flux-ropes using the FRED model (Gopalswamy *et al.* 2017) for the three CMEs listed in Table 1. B_0 of the coronal flux ropes at 10 R_S for these events ranges between 32 to 130 mG for both the PEA and FRA methods, whereas using the MC fitting method (Wang *et al.* 2016) we have found that B_0 of the associated MCs at 1 AU ranges between 9 to 43 nT. The average observed value of B_0 for the MCs at 1 AU is $\approx$ 22nT for these three events. This value is almost two times larger than the average inferred value of B_0 ($\approx$ 13 nT) at 1 AU assuming the self-similar expansion of the CMEs. Comparing the orientation of the flux-rope axis we have found that the MCs at 1 AU show 80 to 110° deviation from the initial orientation near the Sun. This significant deviation in the axis orientation of the MCs suggests that the interplanetary deflection and rotation of the CMEs need to be quantified in order to predict the geo-effectiveness of the associated ICMEs.

Acknowledgements

References

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