Initiation of Coronal Mass Ejections and the Associated Solar Flares

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Abstract

What role magnetic reconnection plays in the initiation and evolution of the CME eruptions is still not clear. In a recent work by Zhu et al. (2020), we conducted a statistical study of 42 CME-flare events. We found a significant correlation between CME acceleration and flare reconnection in various aspects, suggesting that flare reconnection is key to acceleration of both fast and slow CMEs and may dominate the acceleration of fast CMEs. We also analyzed time lags of the peak CME acceleration relative to flare reconnection rate, and found that, on average, acceleration-led events have a smaller reconnection rate, and are likely driven by ideal instabilities. To further probe what mechanism triggers the eruption, in this study, we focus on the early-stage evolution of CMEs, flare reconnection, as well as hard X-ray bursts, using a subset of CME-flare events well observed with high temporal and spatial resolutions by SDO, STEREO, and RHESSI. We examine the tempo-spatial relationship between the CME acceleration and flare signatures in the low corona, and compare onsets of CME acceleration and flare reconnection in these events.

Introduction

Motivation

- Examine when and how the CMEs and flares are initiated and erupted.
- Study how CME acceleration depends on reconnection.

Instruments

- STEREO A&B imagings are used to track the CMEs with EUVI (0–1.7 $R_\odot$), COR1 (1.3–4 $R_\odot$), and COR2 (2–15 $R_\odot$).
- SDO is used to measure the magnetic reconnection flux, to to track the early-stage evolution of CME-flare events.
- RHESSI is used to study the X-ray imaging and spectrum of both preflare and implusive phases.
- 42 events are chosen and analyzed alongside magnetic reconnection flux derived from SDO.

Measurement of reconnection flux

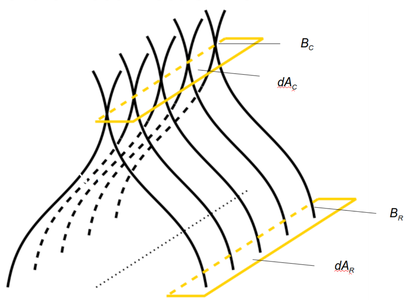

Figure 1: Magnetic reconnection flux.

Reconnection flux [Forbes & Priest, 1984]:

$$F_{rec} = \int B_c dA_c = \int B_R dA_R$$

Method and Statistics

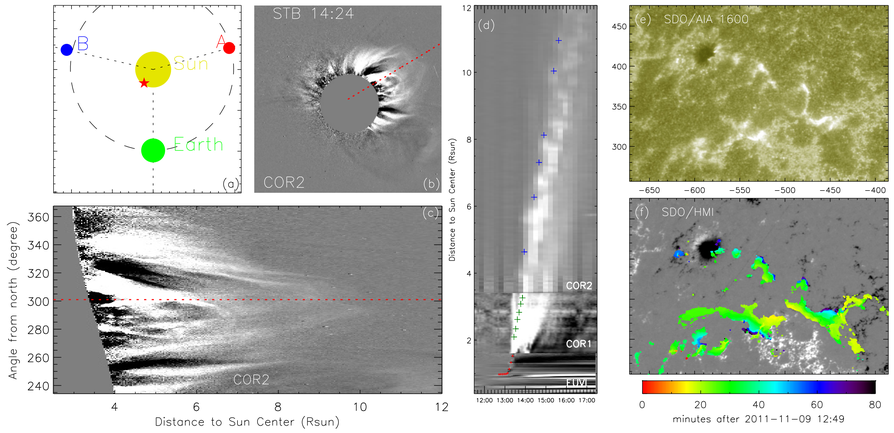

Figure 2: A CME eruption observed on 2011 Nov 09 by STEREO-B (a–c), the CME trajectory (d, J–map), and evolution of its associated flare ribbons (e&f).

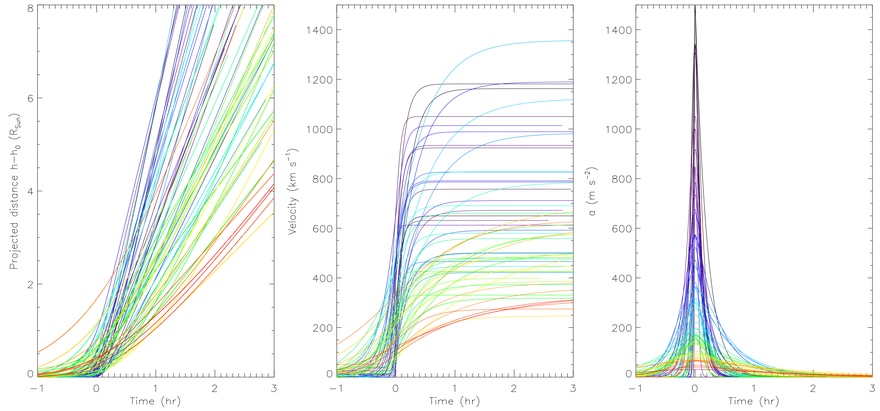

Figure 3: Overview of the kinematics of the selected CME-flare events.

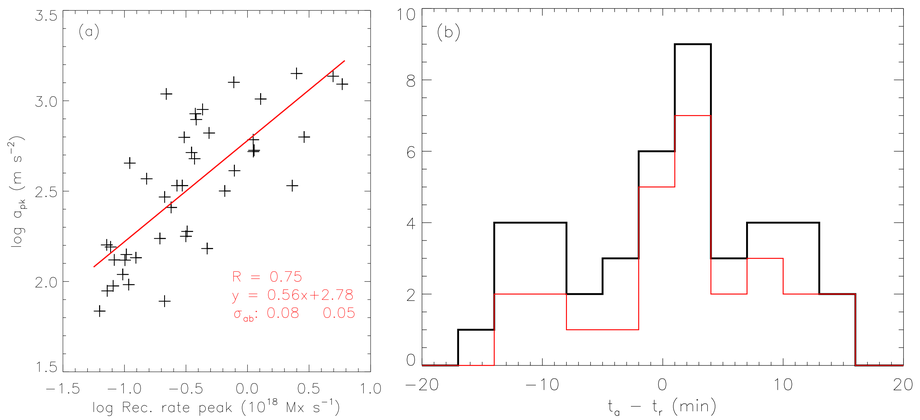

Figure 4: (a) Relationship between the peaks of the acceleration and reconnection rate. (b) Distributions of the time differences between the profiles of acceleration and reconnection rate, where a negative time difference here means that the acceleration profile comes earlier, and vice versa.

Case Study

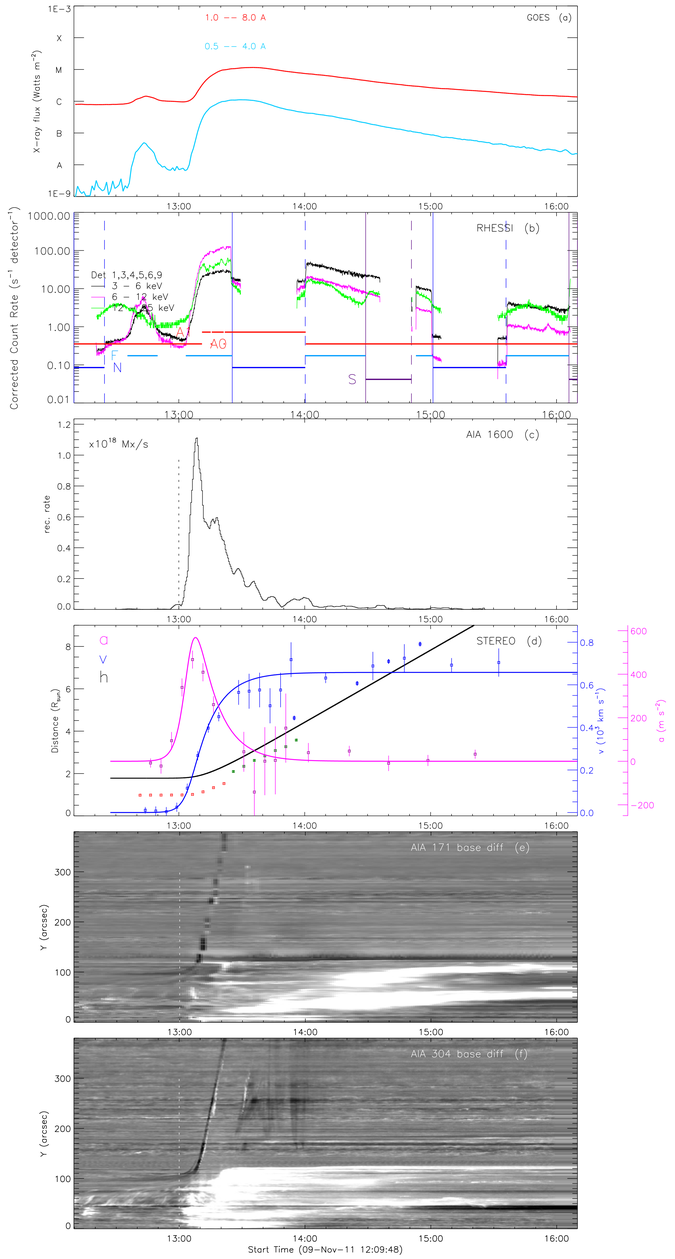

Figure 5: A case study of a CME-flare event on 2011 Nov 9 about the initiation and early-stage evolution of the eruption.

Reference

Zhu *et al.* 2020 ApJ 893 141