Magnetic Sources of Coronal mass Ejections

1. Energy storage
2. Energy release impulsively by reconnection (X point or no X point)
3. Transport of CME through Solar Wind (models)
4. Evacuation of the excess of helicity through CME

Rio de Janeiro  STP11 March 7 2006
1. Energy storage in the region

shearing structures: sigmoids

Increase of the magnetic stress by emerging flux or cancelling flux
Expanding sigmoids observed with Yohkoh/SXT On 25 Oct. 1994 (AR 7792)

\[ \nabla \times \mathbf{B} = \alpha \mathbf{B} \]

Magnetic extrapolations indicate high non-potentiality

(Manoharan et al 1996)
How does sigmoid eruption happen?

(a) Pre-ejection configuration

(b) Reconnection forms two sets of loops $\Rightarrow$ sigmoid

Sigmoid formation by reconnection of two J-shaped loops and cusp formation after the ejection (van Driel-Gesztelyi et al, 2000)

(c) Sigmoid expands $\Rightarrow$ current sheet formation under it $\Rightarrow$ cusped reconnected loops

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Stress redistribution by cancelling magnetic flux for CMEs

CME on 25-26 September 1996
decaying active region (MDI)

Coronal hole (Yohkoh/SXT)

CME (LASCO)

(van Driel et al. 1998)

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October/November 2003

AR 486: ten X flares

CME (LASCO C2) \( v = 1785 \text{ km/s} \)

28 Oct. X17:
large dimmings and trans-equatorial loops

EIT 2003/10/28 07:25

Rio 2006
Magnetic field evolution between Oct 24 and 1 Nov. 2003

Emerging active region in an old AR: successive emergences of bipoles creating a complex δ region (AR 10486)

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AR 10486
October 28, 2003

It is a quadrupolar magnetic region

High shear region

Vector Magnetic field
Huairou

THEMIS/MSDP (Na D1)

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2006
2. Energy release by reconnection: Magnetic ‘breakout’ in a quadrupolar region

- Break of the lines
- Heating 4 ribbons
- X point
- CME

(Antiochos et al 1999)

Rio de Janeiro  STP11 March 7  2006
Global quadrupolar reconnection 2 min. before the X flare

Four ribbons between 10:12-10:19 UT between 10:47-10:58 UT

Break the overlying field

(Mandrini, Démoulin, Schmieder et al 2006)
Quadrupolar region: model with no X point but QS

Topology / geometry:
- Continuous field line mapping
- Sharp connectivity gradients

(Aulanier, Pariat, Démoulin 2006)

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Slip-running reconnection in 3D

- Field line dynamics:
  - Coronal reconnection
  - Alfvénic continuous footpoint slippage
  - Origin of apparent fast motion of particle impact along flare ribbons?
3. CME with close/open field lines

Flux rope: filament, AR
Non flux rope: coronal hole, open structure

Figure 1

From S.T.Wu

Rio de Janeiro  STP11 March 7
2006
Without loops

With loops

4 hours

7 h

Rio de Janeiro  STP11 March 7 2006  shock

- 2.5 D MHD simulation: wind models, shearing motion

\[ H = -2 \int_{V} A_{\phi} B_{\phi} dV \]

(Wind models, Phys. cond.)

Helicity: threshold

One CME

Shearing velocity

(Jacobs and Poedts 2006)
Increasing magnetic stress + Suitable magnetic topology → CME: helicity valve
Breakout model

The end

Rio de Janeiro  STP11 March 7
2006