PHYSICAL LINK BETWEEN CMEs AND MAGNETIC CLOUDS: THE COMBINE BENEFIT OF THE STEREO MISSION AND MAGNETIC HELICITY CONSERVATION

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Why magnetic helicity ?

- Intrinsic property of the physical process
  e.g. Inverse MHD cascade, build up of twisted flux rope
- Conserved quantity
  $\Longrightarrow$ track the magnetic flux from its formation to the heliosphere

Magnetic flux travel

Heliosphere (1 AU)	10^{-8} T	(10^{-4}G)	expansion, relaxation (MC)
Corona (low)	10^{-2} T	(10^{2}G)	accumulation, unstability
Phostosphere	10^{-1} T	(10^{3}G)	expansion, relaxation
Convective zone			transport
Tachocline	10 T	(10^{5}G)	dynamo, Parker unstability

Magnetic helicity: main features

- Definition of the **relative** magnetic helicity

$$H_r = \int_V \vec{A}.\vec{B} dV - \int_V \vec{A}_0.\vec{B}_0 dV$$

with:

$$\vec{B} = \vec{\nabla} \times \vec{A},$$

and, $\vec{B}_0$: potential magnetic field.

- H_r is **gauge-invariant** $(\vec{A} \rightarrow \vec{A} + \vec{\nabla}\Phi)$

(Berger & Field 1984, Finn & Antonsen 1985)

- **Conservation** of H_r

$$\left|\frac{\Delta H_r}{H_r}\right| \leq \sqrt{\frac{\Delta t}{\tau_d}}$$

with:

$$\Delta t = \text{evolution time}$$

$$\tau_d = L^2/\eta \,(\text{diffusion time})$$

(Berger 1984)

- **Hemispherical rules** ($H_r < 0$ in the northern hemisphere)

(Seehafer 1990, Pevtsov et al. 1995, Bothmer & Rust 1997)

- **Accumulation of H_r** in the corona $\Longrightarrow$ CMEs

(Rust 1994, Low 1996)

Input of helicity in ARs

* Magnetic helicity input at the photosphere:

$$\frac{dH_r}{dt} = \quad \text{helicity flux}$$

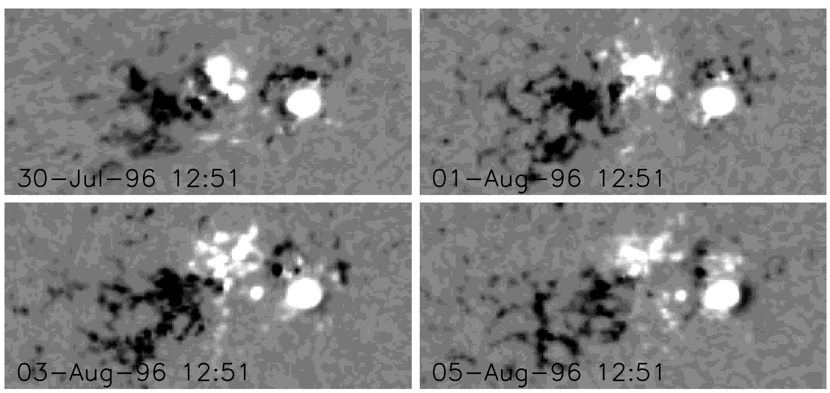
$$+2\int_S (\vec{A}_0.\vec{B})(\vec{v}.d\vec{S}) \quad \text{emergence}$$

$$-2\int_S (\vec{A}_0.\vec{v})(\vec{B}.d\vec{S}) \quad \text{differential rotation}$$

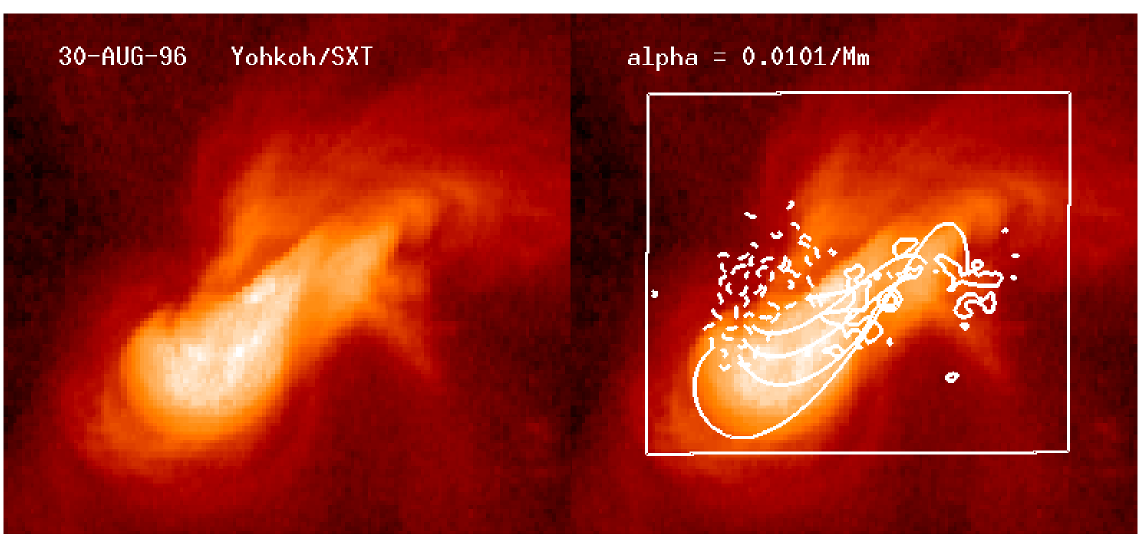
$$+ \quad \text{shearing motions}$$

(note: can select $\vec{A}_0.d\vec{S} = 0$)

* Evolution of $B_{//}$: from SoHO/MDI in AR 7978



* Coronal helicity: from SXT/Yohkoh and lfff extrapolation



Input of helicity in two ARs

* Long-term evolution of two ARs:
  - AR 7978: **6** rotations
  - AR 8100: **5** rotations   poster: Green et al.

  with: Yohkoh/SXT, SoHO/MDI

* For the two ARs:

Both differrential rotation & shearing motions

- **do NOT** bring enough magnetic helicity in the corona
  (up to a factor 10)
- could be of **opposite sign** as $\Delta H_{\rm corona}$

$\Longrightarrow$ importance of **emergence & torsional Alfvén waves**

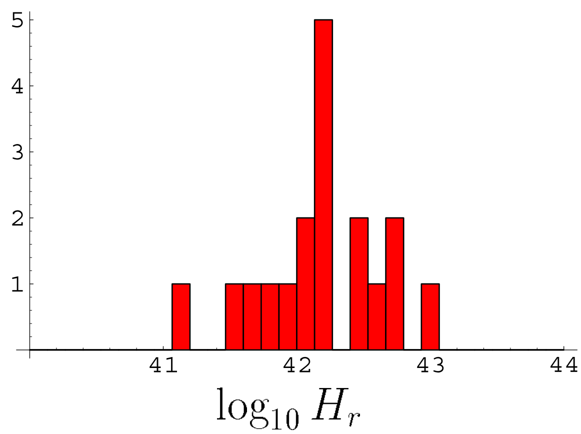
(Démoulin et al. 2002, Green et al. 2002)

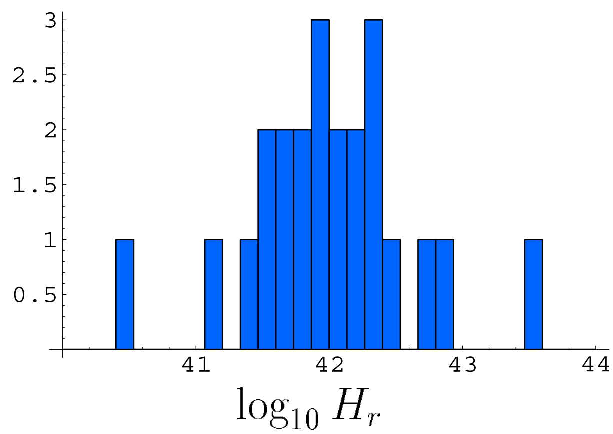
Ejection of magnetic helicity

* How to estimate the magnetic helicity ejected ?

- identification of **all CMEs** lauched from **an AR**
  with: SoHO/(EIT,LASCO)
- no $\vec{B}$ measurement in CMEs
  $\Longrightarrow$ assume: $< H_{CME} >=< H_{MC} >$
- **In situ measurement** of $\vec{B}$ in MCs
  \+ **model** (lfff) $\rightarrow H_{MC}$

* Magnetic helicity in magnetic clouds





deduced from: Lepping et al. 1990 — 18 MCs

Zhao et al. 2001 — 23 MCs

assume a MC length = 0.5 AU

$\Longrightarrow \quad < H_{MC} >\approx 2.10^{42}\ \mathrm{Mx}^2$

Ejection of helicity from two ARs

* Long-term evolution of two ARs:

- AR 7978: 6 rotations
- AR 8100: 5 rotations   poster: Green et al.

with: Yohkoh/SXT, SoHO/(MDI,EIT,LASCO)

* Magnetic helicity ejected:

AR	N_{CME} observed	N_{CME} corrected	H_{MC} (CME obs.)	H_{MC} (CME cor.)	$H_{\rm diff.rot.}$
7978	26	31	52.	62.	8.
8100	19	41	38.	82.	-7.

(in unit of 10^{42} Mx^2)

Note: assume $L_{MC} = 0.5$ AU (**only !**)

$\Longrightarrow$ **differrential rotation do NOT bring enough magnetic helicity !**

(Démoulin et al. 2002, Green et al. 2002)

Result $\neq$ DeVore (2000)

difference: sensitivity & duty cycle of the SMM / SoHO coronographs

Input of STEREO

- **Photosphere:** Input of magnetic helicity by:
  - differential rotation
  - shearing motions
  - emergence $\Longrightarrow \vec{B}$: ASP, THEMIS, SOLAR B

- **Corona:**

  Determine **3D** magnetic configurations: EUVI/SECCHI
  (+ magnetograph)
  "loop organisation" $\Longrightarrow$ coronal magnetic helicity

- **Heliosphere:**
  - local measurements of $\vec{B}$ with magnetometer: MAG/IMPACT
    + MC model $\Longrightarrow$ MC magnetic helicity
  - "lucky case": detection by STEREO #1 & #2 of the same MC
    $\Longrightarrow$ differences in the local properties

- **Link Corona-Heliosphere:**
  - **associate a given MC to a CME:**
    coronographs + heliosphere imager of SECCHI
  - **combine global and local measurements**
    with the constraint of magnetic helicity conservation

is a CME the result of coronal helicity build up ?