Magnetic Helicity and Free Energy Injection in Emerging Active Region

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Summary

The magnetic helicity, H, quantifies the degree of linkage and/or twistedness in the magnetic field. The free magnetic energy, E, quantifies the excess energy stored in a magnetic configuration. The free magnetic energy can be extracted and converted to other forms only when the field deviates from potential state. The importance of storage and release of free magnetic energy in ARs has been widely studied for solar eruptions (e.g. Schrijver, 2009). However there are few studies on the role of magnetic helicity (Nindos and Andrews, 2004; Tziotziou et. al, 2012). We investigate the role of magnetic helicity and magnetic energy injection in the destabilization of emerging ARs. Using vector magnetic field data from the Helioseismic and Magnetic Imager instrument aboard the Solar Dynamics Observatory, we calculate the magnetic helicity and magnetic free energy injection into the corona in 34 emerging ARs. For each AR these quantities were monitored from its emergence until it reached a heliographic longitude of 45-50 degrees or until the occurrence of the first coronal mass ejection associated with it. We find a partial segregation of both helicity and magnetic energy in eruptive ARs from non-eruptive ARs. We also notice that a sufficient amount of magnetic free energy and magnetic helicity must be stored into the corona prior to eruptions.

Method

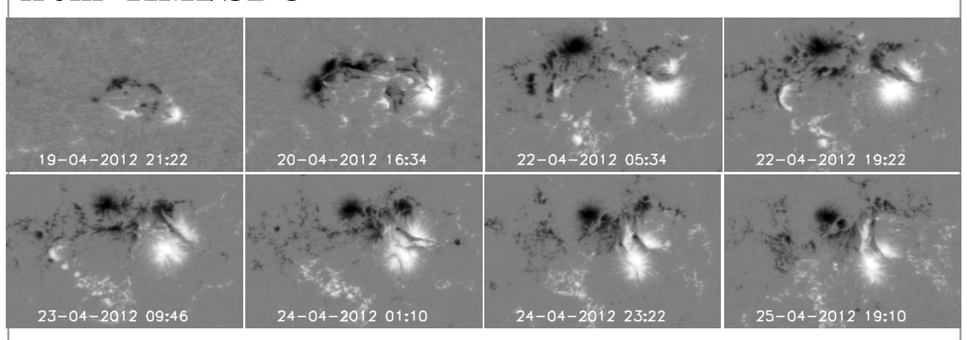
- Use Vector Magnetic Field with cadence of 12 min.
- Compute horizontal velocities using DAVE4VM (Schuck, 2008).
- Compute the helicity flux density using the G_θ as proxy (Pariat et al. 2005, 2006). The G_θ is calculated using FFT (Liu and Schuck, 2013).

$$G_\theta = -\frac{B_n}{2\pi}\int_{S'}\frac{d\theta(r)}{dt}\,B_n'\,dS'$$

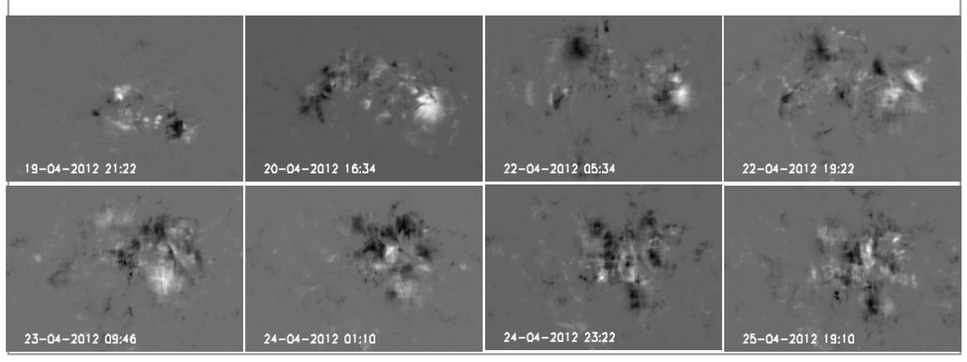
- Compute total accumulated magnetic helicity and free magnetic energy injected into the corona.

Evolution of AR 11465

Snapshots of evolution of the Bz component from HMI/SDO

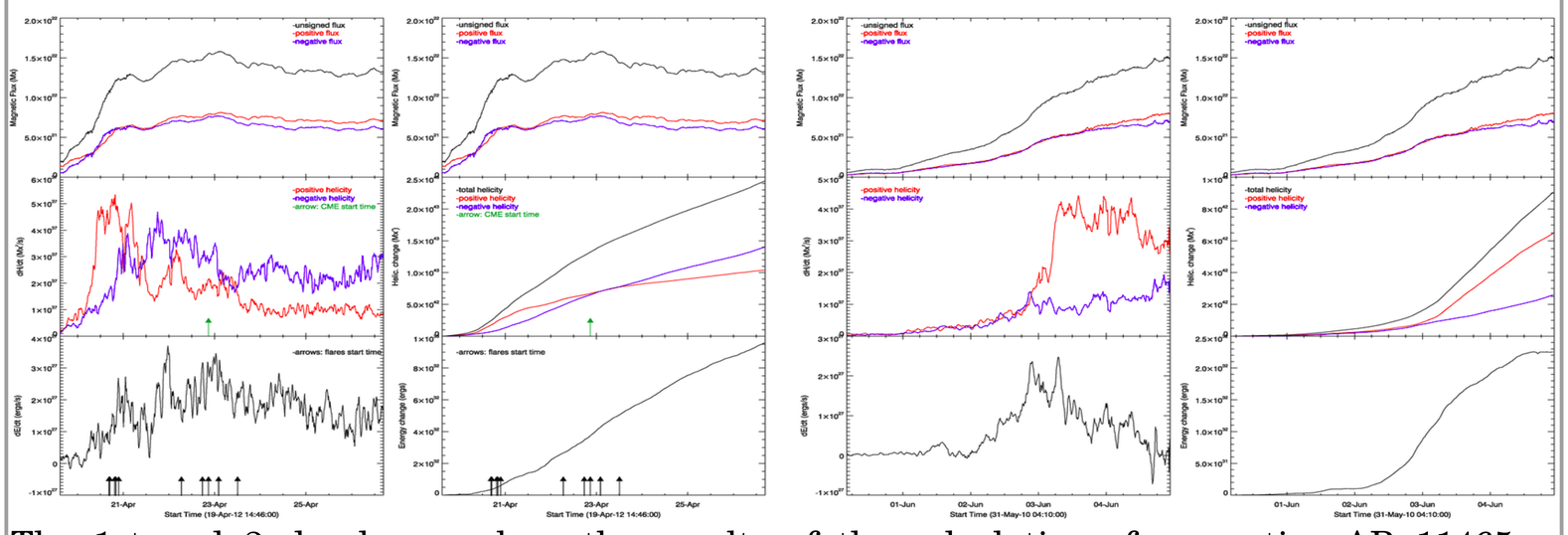


Snapshots of evolution of the G_θ



Computations - Results

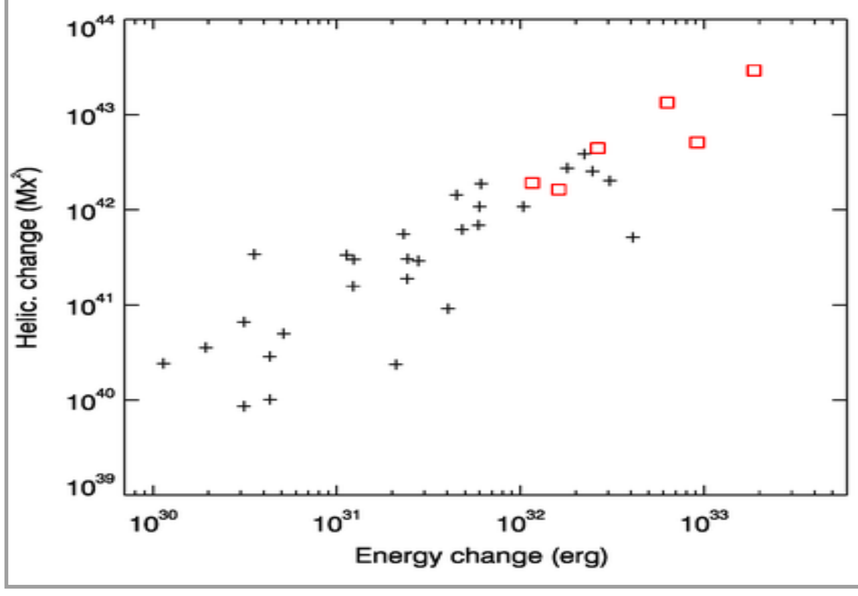
Eruptive AR 11465 — Non-eruptive AR 11076



The 1st and 2nd columns show the results of the calculations for eruptive AR 11465 and the 3rd and 4th columns show the results of the calculations for non-eruptive AR 11076. In particular, we see:

1st & 3rd columns: Top: Magnetic flux. Middle: Time profile of positive and absolute negative values of dH/dt. The green arrow indicates the time of the first appearance in the LASCO images of the CMEs originated from the active region. Bottom: Time profile of dE/dt. The black arrows indicate the start time of the flares that occurred in the AR. The horizontal axis indicates the time.

2nd & 4th columns: Top: Magnetic flux. Middle: Time profile of accumulated change of helicity ΔH(t) calculated from the measured dH/dt. Bottom: Time profile of free magnetic energy ΔE(t) calculated from the measured dE/dt. The horizontal axis indicates the time.



Left: The energy change - helicity change diagram of solar ARs. Red square correspond to eruptive ARs and the plus sign (+) correspond to non eruptive ARs. For magnetic helicity over (~2×10^{42} Mx^2) and free magnetic energy over (~1×10^{32} erg) see eruptive ARs. We notice that a sufficient amount of magnetic helicity and free magnetic energy is stored in the corona prior to eruption.

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Conclusions - Future work

- Partial segregation in both magnetic helicity and magnetic free energy of eruptive ARs from non-eruptive ARs.
- Sufficient amount of magnetic helicity (~2×10^{42} Mx^2) and magnetic free energy (~1×10^{32} erg) must be stored into the corona prior to eruption.

Future work

Repeat the above work for the remaining 21 ARs of the sample.