SOLAR SIGNATURES & ERUPTION MECHANISM OF 14 AUG 2010 CME

DON'T JUDGE A CORONAL MASS EJECTION ON THE STRENGTH OF ITS ACCOMPANYING FLARE!

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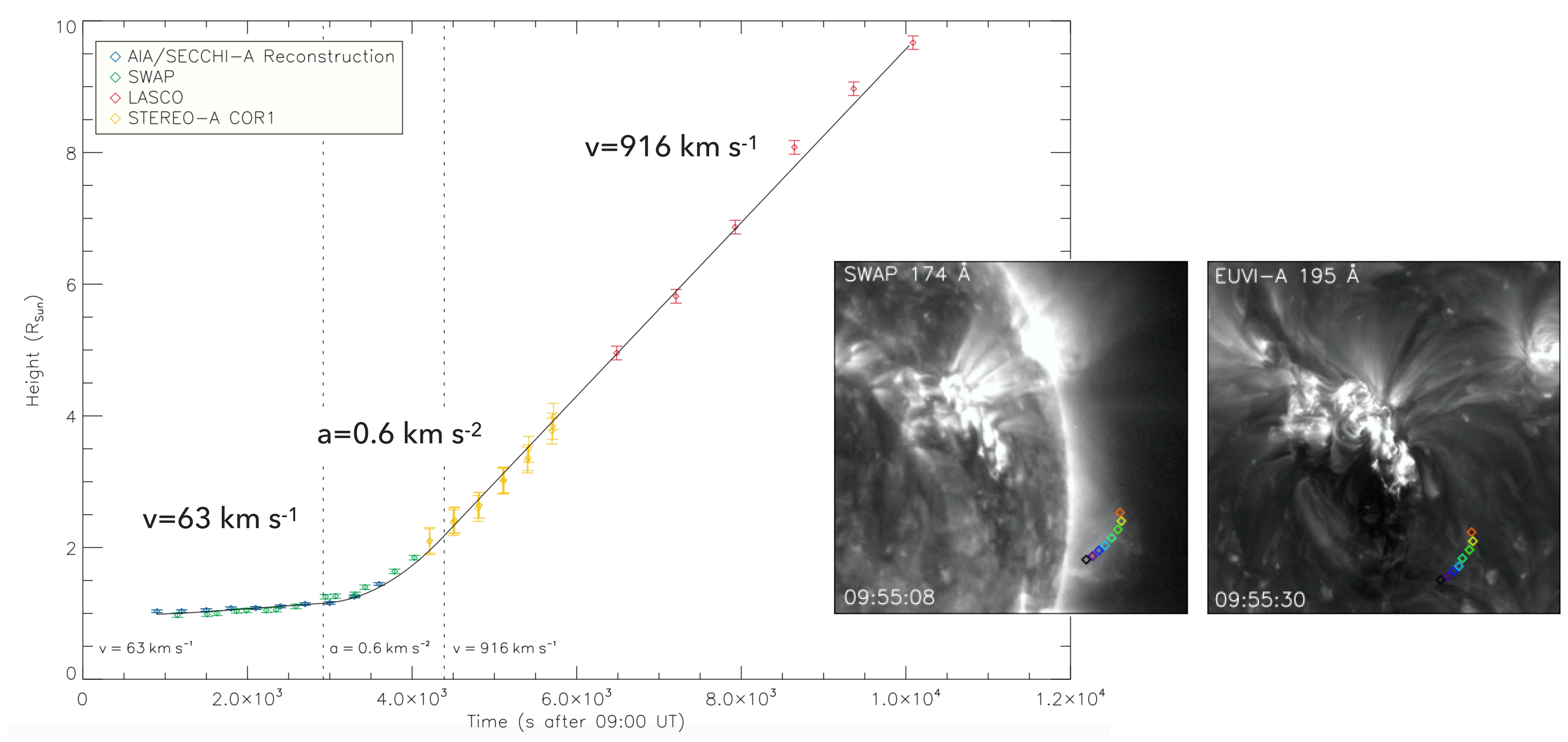
Introduction

Solar Coronal Mass Ejections (CMEs) and solar flares are some of the main drivers of Space Weather, a field that aims at forecasting the effects of solar activity (and other space-related events) on Earth and its technology. Although there is a vast amount of data available from a fleet of satellites and ground observatories, estimating the impact an observed CME will have on the Earth is complicated.

A good example to illustrate this is the wide-angled CME observed on August 14, 2010, one of the first strong eruptions of the present cycle 24. It originated from a destabilized filament that connected two active regions (ARs) and has been observed from 3 viewpoints: Earth and both STEREO spacecraft at 80° ahead and 72° behind Earth. It propagated outward at high speed creating a shock and solar energetic particle (SEP) event but nevertheless was only accompanied by a weak C4.4 flare. Although flare strength is often used as an indication to estimate the potential impact of a CME, it would have severely underestimated the space weather risk of this event. We study the event in detail to find out why.

CME trajectory and kinematics

To study trajectory, kinematics and CME morphology, a 3D reconstruction was performed. Epipolar geometry techniques were used on PROBA2, SDO (both Earth view) and STEREO EUV and coronagraph data to determine true CME propagation direction and speed from initiation up to 10 solar radii.



The resulting height-time diagram clearly shows 3 different regimes:

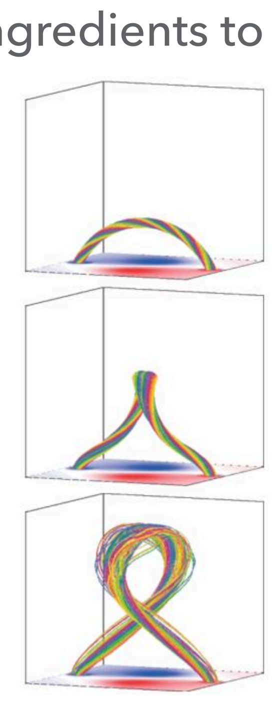
- destabilisation phase: initial rise of filament at very low velocity
- CME initiation: catastrophic eruption leads to rapid acceleration
- propagation phase: constant, very high velocity

CME initiation mechanism

Understanding the physical characteristics of a CME, its association with a solar flare, and ultimately its potential space weather impact, needs insight in why and how it erupted. The required energy to power a strong CME can only come from the magnetic field. Coronal flux ropes are held in equilibrium by a balance of magnetic pressure as outward force, and magnetic tension of surrounding field as inward force. An (often slow) restructuring of the field, eroding the equilibrium, and a (sudden) trigger are the crucial ingredients to initiate an eruption.

CME initiation process on Aug 14, 2010:

- 13 Aug: Start decrease in average magnetic flux on southern end of filament: flux cancellation as destabilisation process.
- 08:50: Southern part of the filament starts to rise. Small brightenings are sign of reconnection below the filament.
- 09:50: Sudden strong unwinding motion, shearing flux rope apart. Rapid acceleration, dragging whole filament with it. -> MHD 'kink instability' as CME trigger (see modelled example)
- During eruption, magnetic reconnection takes place, causing formation of bright flare loops, connected with the C4.4 X-ray flare.

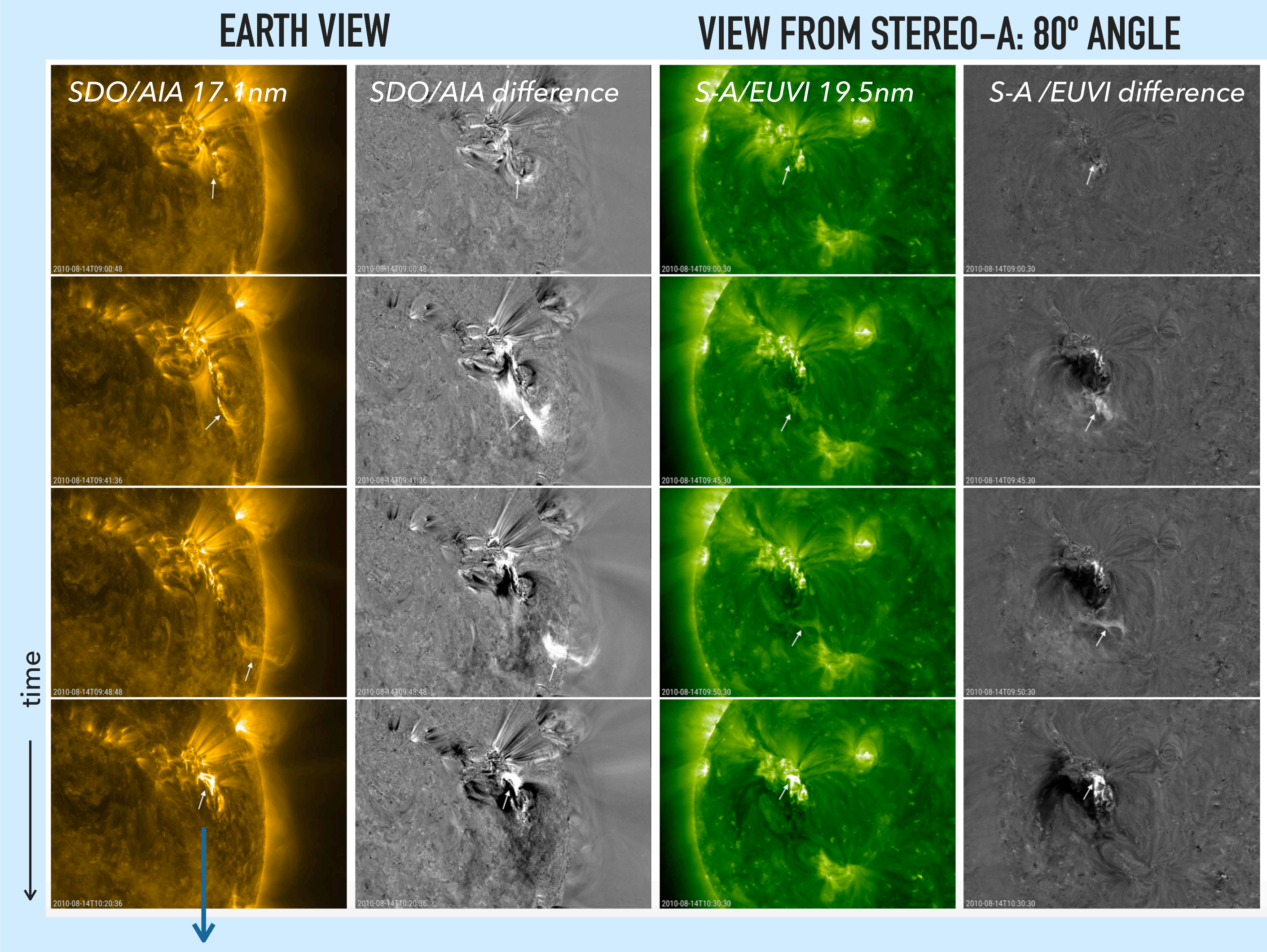


Simulated flux rope ejection; T. Torok & B. Kliem

The flare is a consequence of the eruption rather than the driver, which may explain why it is so weak seen the rapid CME acceleration.

Solar & interplanetary signatures of 14 August 2010 event from 3 viewpoints

EUV DATA: SOLAR ERUPTION IN STEREO-VIEW

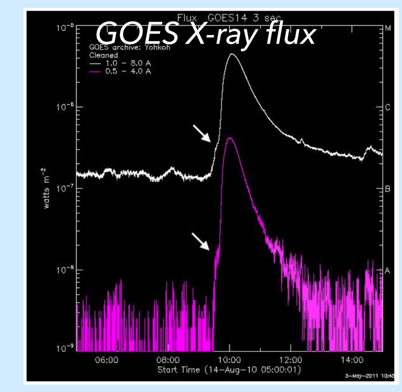


8:50: Rising filament

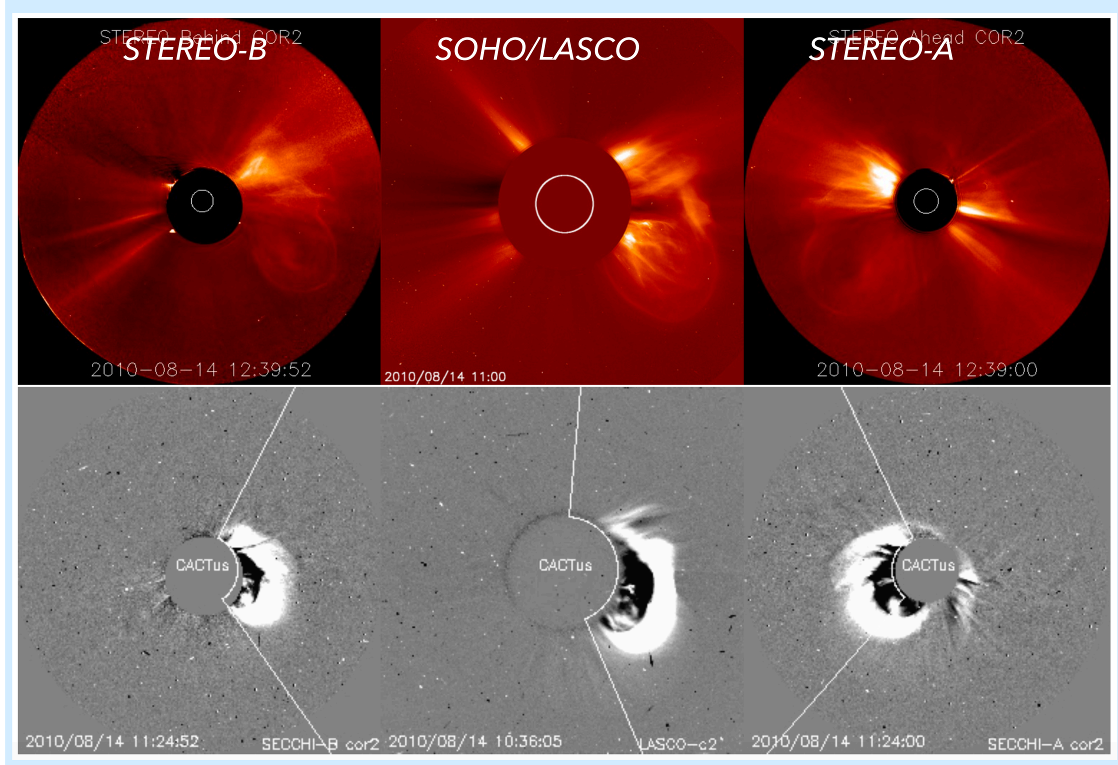
9:30-9:50: Unwinding motion during eruption

10:05: Solar C4.4 flare. (Post-) flare loops build up lasting several hours. Dimming (darkening) regions in EUV indicate evacuation of coronal plasma

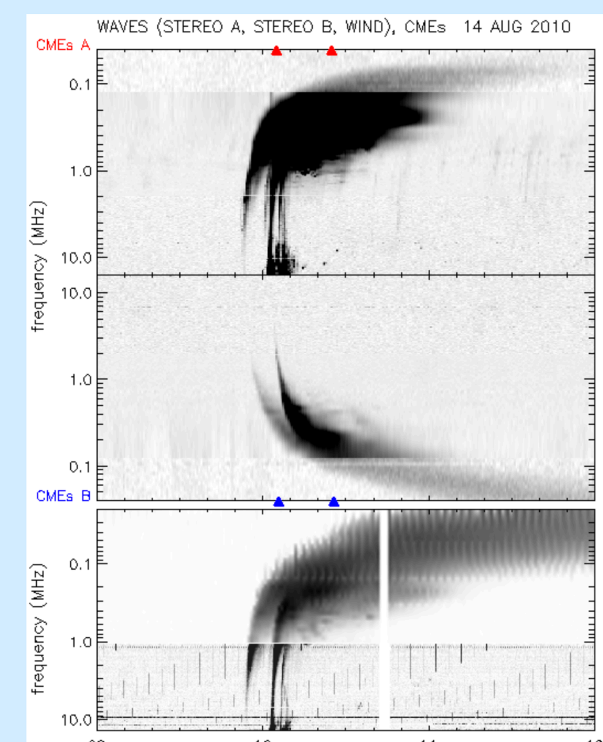
X-RAY DATA



WHITE LIGHT CORONAGRAPHS: CME PROPAGATION



RADIO DATA: SHOCK FROM 3 VIEWPTS



A wide-angle CME is observed from all viewpoints, heading West. Also the automatic CME detection software CACTus detected events in all 3 datasets, with speeds (in plane of the sky) of 570 to 660km/s.

Radio spectra show both type II bursts (electrons accelerated at a CME shock) and type III bursts (associated with the solar flare).

PROTON FLUX: SOLAR ENERGETIC PARTICLE EVENT

A strong increase in proton flux was measured for proton energies >10MeV, peaking at 12:45. The radiation storm at Earth was minor as the bulk of the CME passed between Earth and STEREO-A.

IN-SITU DATA show the arrival of a CME shock front at STEREO-A. Earth's magnetic field stays relatively undisturbed, but **a strong CME+SEP would have hit Earth if it had left a few days earlier**.

EVENT TIMELINE

Conclusions

The solar eruption on Aug 14, 2010 caused a fast CME, strong interplanetary shock and SEP event but was accompanied by a rather weak flare. Analysing data from 3 viewpoints, we conclude the eruption was facilitated through flux cancellation, eroding the magnetic balance, and an MHD instability to trigger the actual CME. The flare being the result of reconnection in the CME wake rather than the CME trigger may explain its weak X-ray emission. This event illustrates that **flare strength is not always a good indicator of space weather risk. All CME properties** have to be taken into account in space weather forecasting, which can only be inferred from **multiple viewpoints.** Also the **state of the interplanetary medium** is crucial, illustrated by Steed et al. (AGU, 2012) who showed that an earlier eruption from the same solar region had similar on-disk signatures, but widely different interplanetary evolution and SW impact. With SOHO/LASCO ageing and loss of communication to STEREO-B, this illustrates the **need for timely, multi-viewpoint coronagraph data** to complement EUV and radio observations in order to **reliably forecast space weather.**

Reference: D'Huys, E.; Seaton, D.B.; De Groof, A.; Berghmans, D.; Poedts, S.; Journal of Space Weather and Space Climate, Volume 7, id.A7, 16 pp.