16th European Solar Physics Meeting

Coronal dimmings associated with CMEs

Skoltech

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UNI GRAZ

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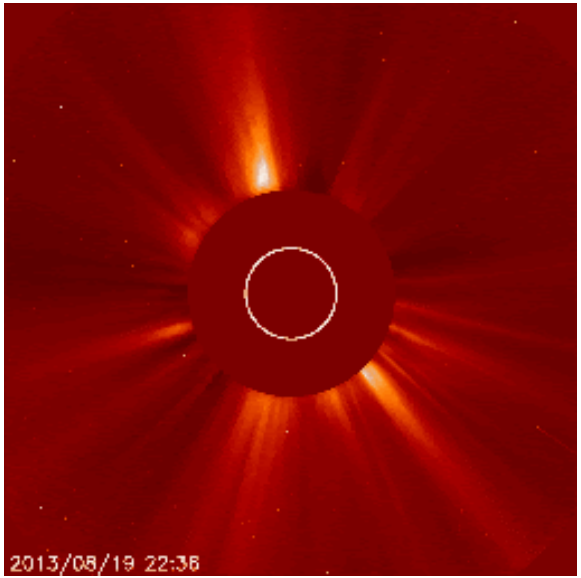
Motivation: CME measurements

Space-based coronographs:

LASCO on SOHO's board (1995 -)

STEREO A (2006 -)

STEREO B (2006 - 2016)



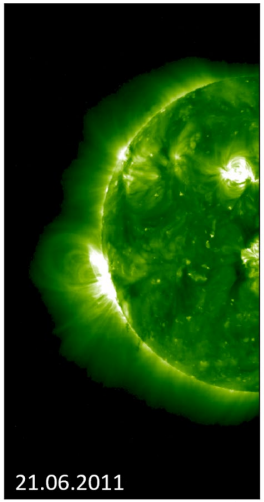
SOHO/LASCO C2

Earth-directed event
2013 August 19

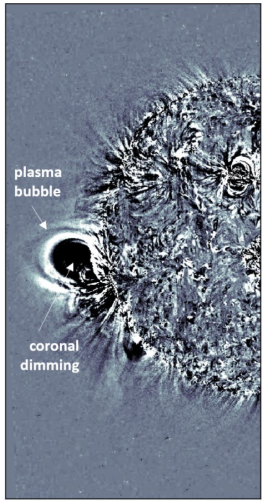
studying not the CME itself but the associated phenomena on the Sun can provide an additional information

Coronal Dimmings

regions of strongly reduced emission in soft X-rays and extreme-ultraviolet (EUV) emission that occur in association with coronal mass ejections in the low corona.
(Hudson et al. 1996; Sterling and Hudson 1997; Thompson et al. 1998, 2000)



STEREO/EUVI 195Å



Log base ratio

Interpreted as density depletion because of the evacuation of plasma during CME event:

- Co-spatial observations of intensity decrease in different wavelengths (Zarro et al. 1999; Chertok & Grechnev 2003)
- DEM analysis: rapid drop of density in the dimming regions (up to 70%), while the temperature drop is not significant (López et al. 2017; Vanninathan et al. 2018, Veronig et al. 2019)
- Spectroscopic observations: plasma outflows in the dimming regions (Harrison & Lyons 2000, Harra & Sterling 2001, Tian et al. 2012)

Data Set

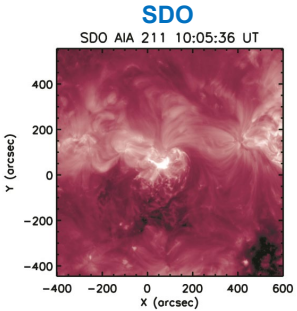
On-disk observations
a series of papers by Dissauer et al. (2018a, 2018b, 2019)

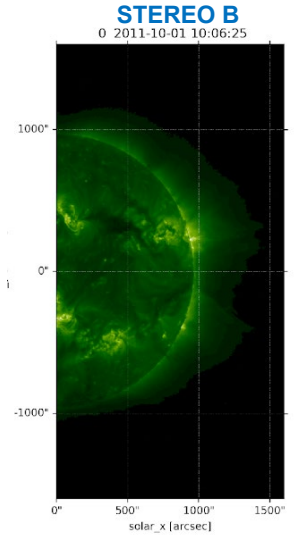
Satellite: SDO (AIA and HMI)
Time range: May 2010 - September 2012
Number of events: 62
Time cadence: 12s

39 events overlap

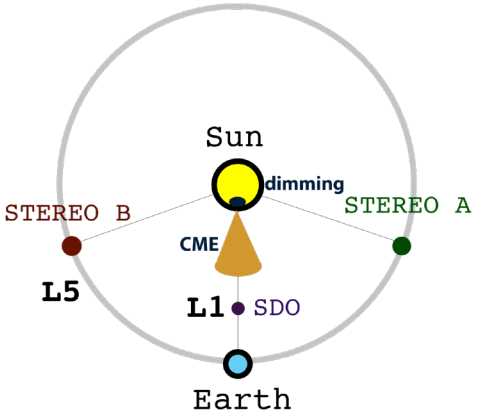
Off-limb observations 195 Å

Satellite: STEREO (EUVI)
Time range: May 2010 - September 2012
Number of events: 43
Time cadence: 5 min
12h of images for each event

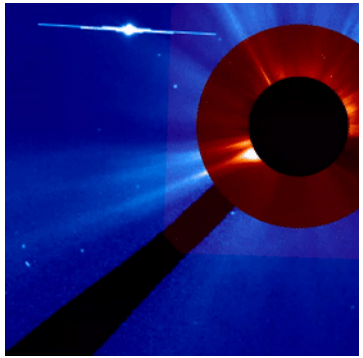




Period of quasi-quadrature of both STEREO and SDO

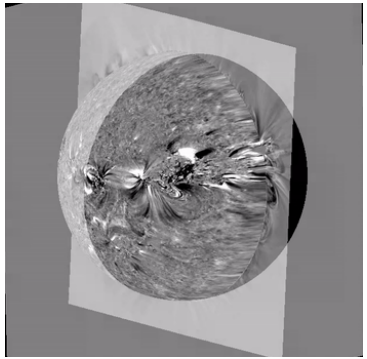


On-Disk and Off-limb observations of Coronal Dimming: 2011 October 1



Original images

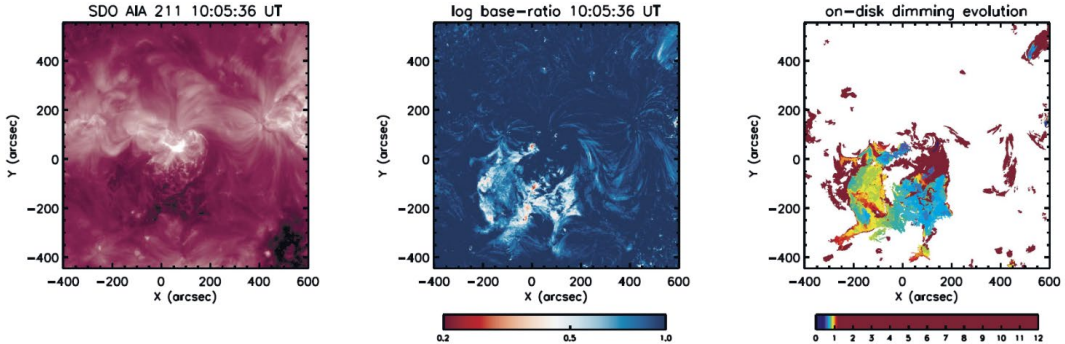
CME from LASCO C2/C3



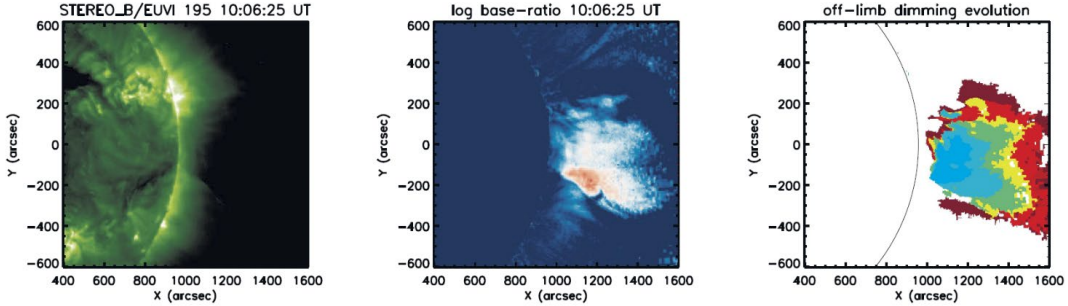
Base Difference images

Coronal dimming from SDO 171Å + STEREO B 195Å

Dimming observations **on-disk** from SDO AIA, described in Dissauer et al. 2019



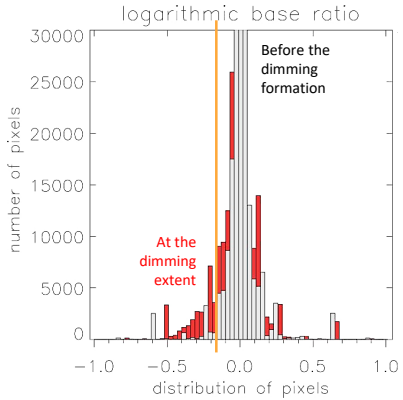
Dimming observations **off-limb** from STEREO EUVI



original data | log base ratio | timing map

For the first time we can compare the results obtained from multiple-viewpoint observations of coronal dimmings

Steps of the segmentation algorithm

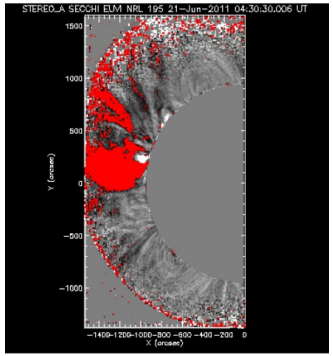


Level of logarithmic thresholding

-0.19

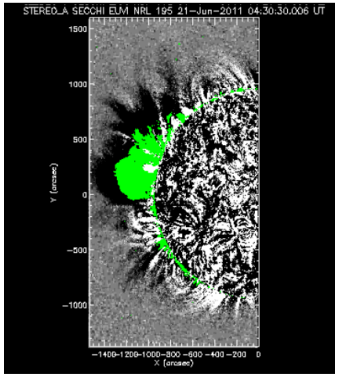
Chosen by the histograms

Log base ratio

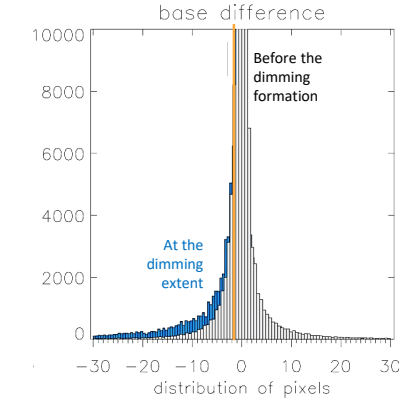


A lot of noise in the upper corona

[3x3] median filtering



Base difference



Level of thresholding

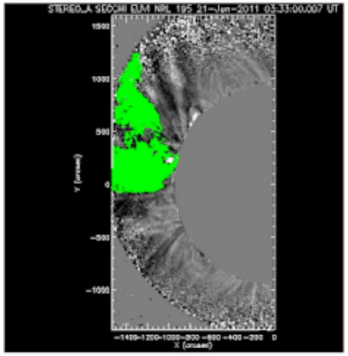
-1.0 DN

+ taking only 30% of the darkest pixels

Region-growing algorithm (Podladchikova & Berghmans 2005)

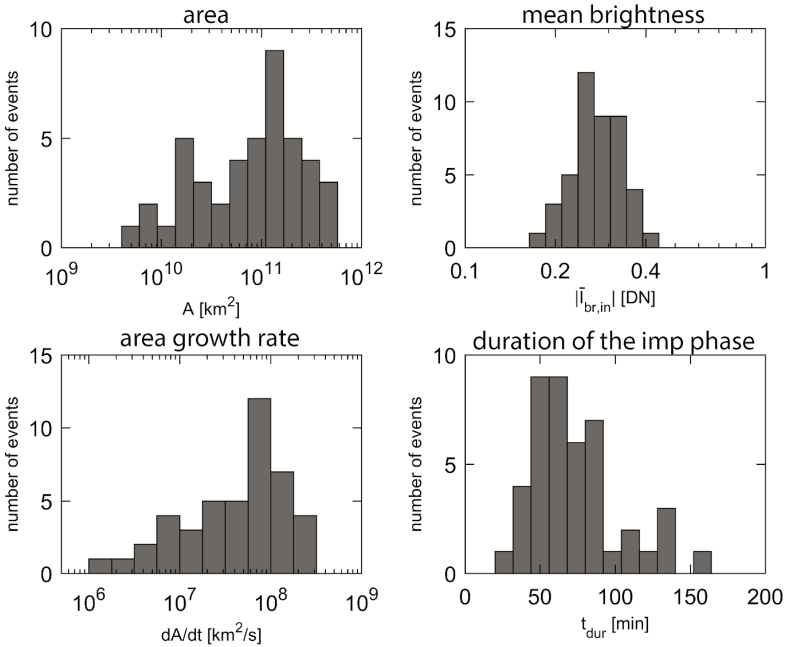
"seed pixels"

Final dimming mask



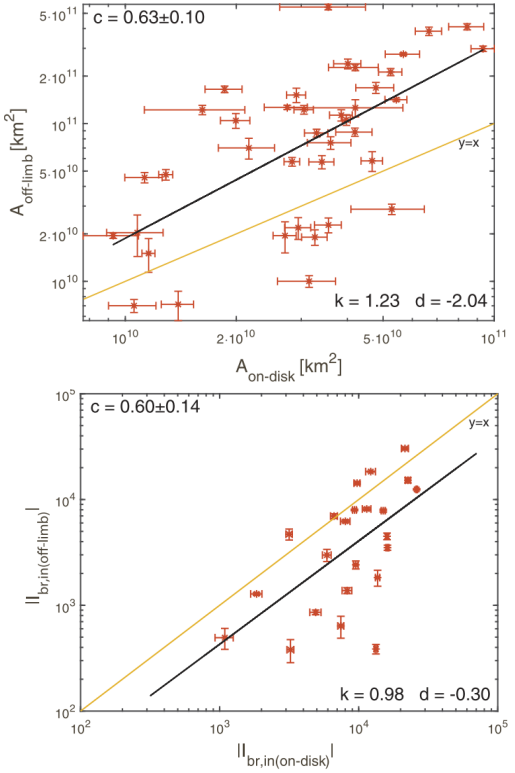
Results

distribution of the dimming parameters



Comparison Between On-disk and Off-limb Coronal Dimmings

Only 8 events under 1:1 line



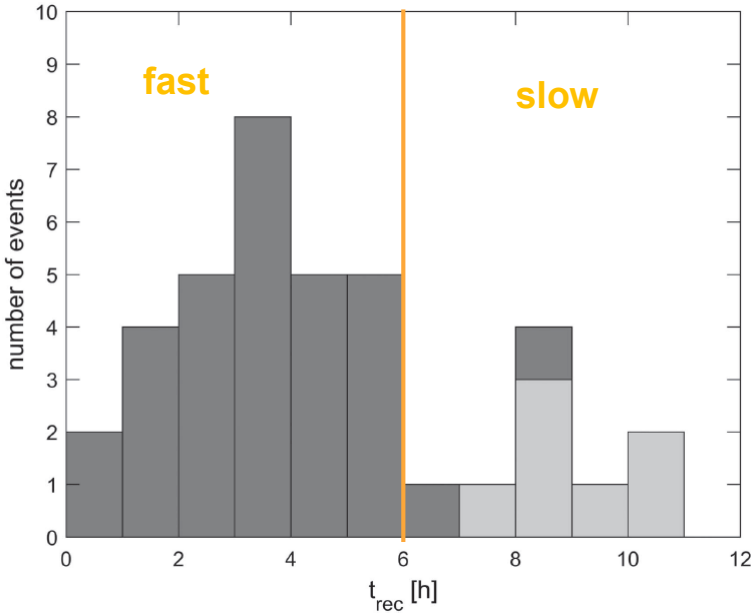
Off- limb dimmings **tend to be larger** than on-disk.

Absolute total brightness from off-limb data tends to be **lower** than the one obtained from the on-disk data

duration if the impulsive phase ~60–70 minutes both for off-limb and on-disk

Results: recovery time

How is the corona recovering after the eruption?



Distribution of dimming recovery times derived from 38 events.

7 events (light colored bars) with only a lower estimate

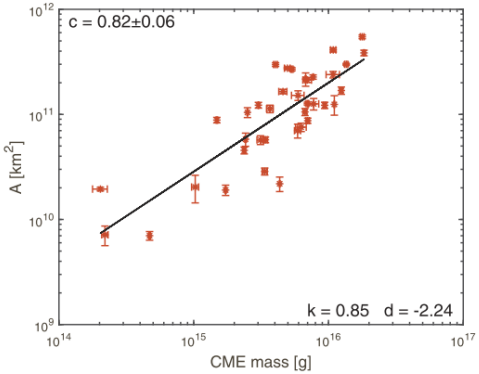
Indicator of how the corona restructures and refills after erupting CME

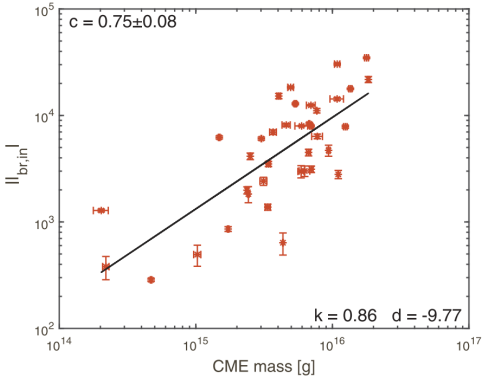
range between max area and falling to 50% of max area

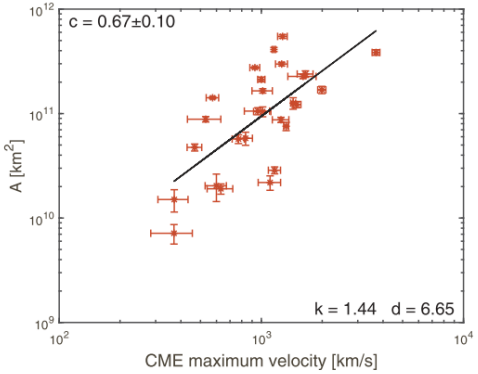
[0.7, 10.9] hrs
mean: 4.6 ± 2.8 hrs
(was also reported in Reinard & Biesecker 2008, Krista & Reinard 2017)

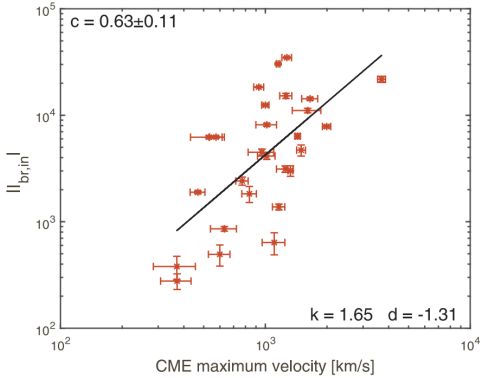
bimodal distribution detected: fast and long recovery

Relation between off-limb dimming and CME parameters







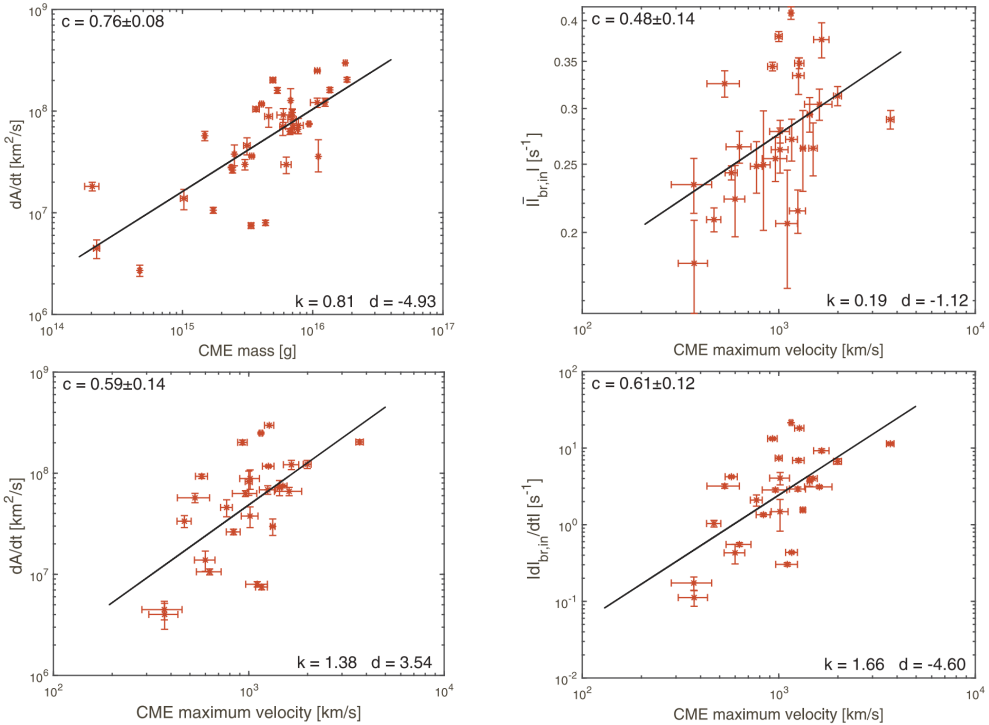


Very high correlation between the dimming **area** and **CME mass:**
the larger the area of the dimming, the more mass the associated CME contains.
On-disk observations: c = 0.69 ± 0.10.

High correlation between the **area** of the dimming and the speed of the CME:
faster CMEs are usually also more massive
(Aschwanden 2016; Mason et al. 2016; Dissauer et al. 2019).

Strong correlation between the **total dimming brightness** and the CME parameters.
Darker dimmings indicate a larger density depletion. CMEs with dark and large dimmings tend to be more massive
(Mason et al. 2016, Dissauer et al. 2019)

Relation between off-limb dimming and CME parameters



High correlation between the **area growth rate dA/dt** and the parameters of the associated CME:
a close connection between the dynamic evolution of the dimmings with the mass and speed of the associated CME.

Moderate correlation of the **mean dimming brightness** and the CME speed:
fast CMEs tend to develop lower in the corona.

The **brightness change rate** strongly correlates with the CME speed:
faster darkening of the dimming indicate higher speed of the CME.

Summary

- We developed a robust automated algorithm for the segmentation of coronal dimmings above the solar limb in STEREO/EUVI 195 Å images.
- The unique location of SDO and STEREO satellites allowed us for the first time to look into the connection of the coronal dimmings and their associated Earth-directed CMEs statistically and compare the results obtained from multiple-viewpoint observations (by Dissauer et al. 2019).
- The relation between coronal dimming and CME parameters was confirmed for the off-limb viewpoint.
- Our findings suggest that coronal dimmings have the potential to provide early estimates of the mass and speed of Earth-directed CMEs, relevant for space weather forecasts, for satellite locations at both L1 and L5.

Chikunova G., K. Dissauer, T. Podladchikova, A. M. Veronig (2020), Coronal dimmings associated with coronal mass ejections on the solar limb, The Astrophysical Journal, 896, 17, 10.3847/1538-4357/ab9105