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Waiting time distribution of emissions in complex coronal mass ejections

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Abstract: The waiting time distribution of emissions in coronal mass ejections (CMEs) with several emissions examined. We define the waiting time as the time interval between the commencement of an emission and the commencement of the next emission considered as parts of a unique CME. The distribution seems to follow a power-law. Two classes of CMEs with several emissions are considered: "close" and "separated" depending on angular distance between emissions.

Introduction

Coronal mass ejections (CMEs) generated in the same location and temporally close can be considered as several emissions of a unique event with several components. In this sense, [1] propose a CMEs classification that involves great scales structures where they also present several emissions cases that would be related physically. In [2] groups of several ejections as parts of unique event lasting a 1-4 days interval are identify. This type of coronal plasma emissions could be related with great scale restructuring processes of solar magnetosphere topology [3].

Forecasting of solar activity impact on Earth needs to consider the possibility of CMEs interactions [4] and CMEs with several emissions would be a key to understand both interactions between emissions and possible particles acceleration processes. In this sense the waiting time between emissions would be a basic parameter in the analysis of the reorganization of the associated magnetic structure in the process of ejections.

We defined waiting time τ as the time interval between the commencement of an emission and the commencement of the next related emission (in location) and its distribution is studied.

Data and classifying methods

The study is based on the CMEs observed by the SMM [5]. Following the criteria in [6] those cases considered as CMEs with two related emissions were selected. To avoid the calculations of the location from which the CMEs were originated, but keeping the idea of unique source of multiple sources of related emissions, we classified them as "close" and "separate" paying attention to the angular distance between the CME central angle reported in [5]. If the central angles differ in more than 20 degrees the pair of emissions were classified as "separate"; if less or equal 20 degrees as "close". The number of events reported in [5] was 1351. The number of events with two emissions selected was 67 ("close") and 46 ("separate").

Results and discussion

We consider the evolution of complex solar magnetic structures to a stable state by ejection process with several emissions. In order to characterize the reorganization process of the magnetic structure the waiting time distribution between emissions was considered. We analyzed the waiting time of 113 CMEs with two emissions classified in "close" or "separate" pairs.

For all events considered (both "close" and "separate"), "close" and "separate" events the waiting time distribution function adjust to a power-law of the type $P(\tau)\propto\tau^{-\gamma}$. The indexes of power-law are:

1.421±0.148 for all events considered (figure 1),
1.677±0.334 for "close" events (figure 2),
1.116±0.198 for "separate" events (figure 3).

In [7] waiting time is defined as the time between two successive ejections considering each one as single, not related one and analyzing its distribution a power-law was found with index 2.36±0.11 using the CMEs observed by SOHO during the period 1996-2001. In this approach, the Sun is considered as a whole generating CMEs not taking into account the intrinsic physical conditions in the magnetic structures evolution.

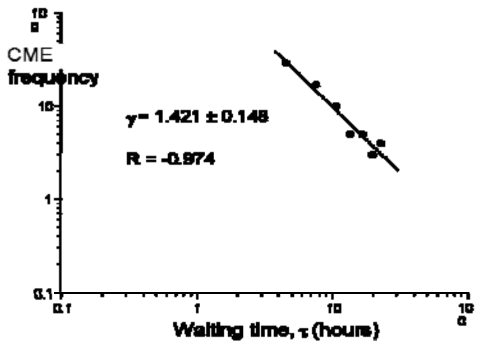

Figure 1: Waiting time distribution of all events examined both "close" and "separate".

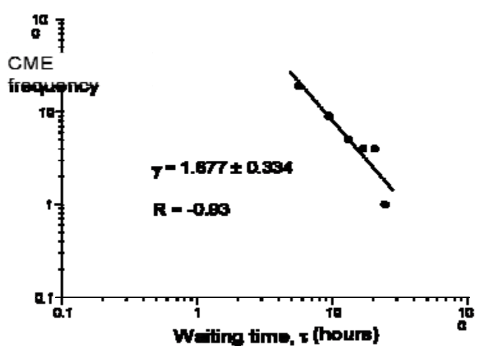

Figure 2: Waiting time distribution of events classified as "close".

Separating the data [7] analyzed two periods: 1999-2001 (maximum of cycle 23) and 1996-1998 (preceding minimum and ascending phase) and found a power-law with indexes 2.98±0.20 and 1.86±0.14 respectively. The difference in the value of power-law indexes was interpreted as a consequence of a variation of the occurrence probability for unit of time of these events with time.

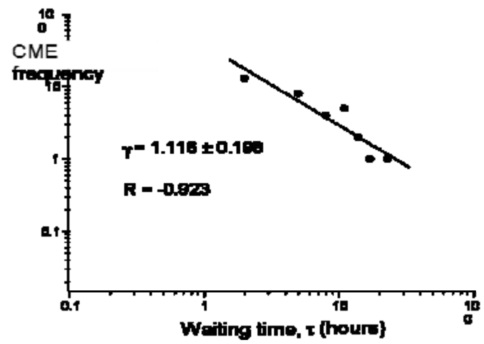

Figure 3: Waiting time distribution of events classified as "separate".

In contrast with [7] we interpret the difference observed in the values of power-law indexes in the waiting time distribution of the CMEs with two "close" and "separate" emissions, as related with the magnetic topology of the structures involved in the process of ejections. For this reason we should expect, for example, greater waiting times for "separate" ones.

Conclusions

The waiting time τ of the CMEs with several emissions is a basic parameter in the analysis of the associated magnetic structure reorganization in the process of ejections. In this work the waiting time of complex CMEs observed by the coronograph on board the Solar Maximum Mission with two emissions is examined and concluded:

1-The waiting time distribution of complex CMEs with two emissions seems to follow a power-law of the type $P(\tau)\propto\tau^{-\gamma}$. This point to the absent of a characteristic time for the waiting time between emissions in complex CMEs with several emissions. This is an important conclusion in order to study the reorganization process of the associated magnetic structure.

2-Both power-law index values for "close" and "separate" events are more like to power-law index value for the years of low solar activity found in [7]. This is because in low activity periods the CMEs waiting time of the whole Sun is much more like our criteria for individual CME phenomena. The probability of CMEs overlapping from different regions is low, so their results

resemble the individual CME phenomenon behavior.
3-The obtained power-law index value in [7] for the period of maximum solar activity, notably separated from the obtained power-law index value for minimum, probably represent the influence of overlapping of CME activity from other regions. In consequence, this overlapping reduces significantly the waiting time increasing the power-law index value.
4-Considering the waiting time τ is related with characteristic spatial length of the CME associated magnetic structure Λ as $\tau \propto (\Lambda/Va)$ where Va is the Alfven velocity, our results are in agreement with the interpretation of two different magnetic scenarios in which the CMEs with several emissions occur. In consequence, CMEs with "close" and "separate" emissions are associated to scenarios with different characteristic spatial length Λ. CMEs with "separate" emissions have a larger Λ than those associated to CMEs with "close" emissions. Then, the relation between values of the power-law indexfor the waiting time for "separate" and "close" events, $\gamma_{\text{"separate"}} < \gamma_{\text{"close"}}$, are in agreement with the relation between characteristic spatial length Λ for "separate" and "close" events: $\Lambda_{\text{"separate"}} > \Lambda_{\text{"close"}}$.

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