Regularities in CME propagation in the current solar cycle according to SWAP/PROBA2, AIA/SDO AND LASCO/SOHO data

Report by Yaroslav Egorov (ISTP RAS)

Aim of the Project

The main goal of the project is to find regularities in limb CME behavior in the new solar cycle at the formation and initial stage of their propagation, using data from PROBA2/SWAP, SDO/AIA and LASCO/SOHO.

In order to study the CME formation and movement during the initial stage, we need data with high temporal and spatial resolution. In 2010 Solar Dynamics Observatory (SDO) spacecraft was launched with the Atmospheric Imaging Assembly (AIA) instrument onboard featuring 12 sec cadence and 0.6 arc seconds spatial resolution. This opens new opportunities for studying CMEs at the early stage of their formation. These opportunities are expanded by SWAP/PROBA2 which has a wider FOV (54 arc minutes versus 41 arc minutes FOV of the AIA instrument).

Data preparation

In our work we've used data which satisfy the following three criteria:

- CME source is near the limb,
- events are observable simultaneously on PROBA2/SWAP, SDO/AIA and LASCO/SOHO images
- it is related to a flare

These data were later processed to better recognize the CME front and other features such as eruptive filament. Several image processing techniques were discussed with the PROBA2 team. Unfortunately, the definition of CME front at high altitudes has not been significantly improved, which practically deprives the SWAP of the wider FOV advantage. But the relatively slow (up to 400km/s) CMEs can be traced to greater heights.

The technique we used is described below:

$$\mathrm{Im} = \frac{I(k) - I(k-1)}{I(0)}, k = 1, n \text{ for SWAP and } \mathrm{Im} = \frac{t_e(0)}{I(0)}\left[\frac{I(k)}{t_e(k)} - \frac{I(k-4)}{t_e(k-4)}\right], k = 4, n \text{ for AIA,}$$

where $I(k)$ is the image at moment k and $t_e(k)$ is the image exposure time at moment k.
In the case of AIA/SDO, we have normalized each image exposure time to a base value, because this parameter may vary from one image to another.

Thus, 8 CMEs have been processed (including 3 CMEs during my stay at P2SC).

For the analysis of the selected events, several IDL routines were written which easily determine the CME front heights by clicking on the image. Based on these heights the program automatically calculates the velocity and acceleration of these structures, as well as other parameters, such as the angular size of CME, CME trajectory, etc. Then this data is automatically recorded in a database for further analysis and charting.
CME velocities obtained by different instruments (SWAP, AIA and LASCO C2) were combined into a single array and interpolated by B-spline function.

Preliminary results and discussion

We've analyzed eight CMEs and found some general morphological features at the initial stage of their propagation: The event begins with the eruption of a filament (four cases) or other loop like structure, then some of the overlying loops become brighter and start moving, which eventually form the frontal structure of CMEs. For most of these events the velocity drops by more than 100 km / s after its maximum, and then, in the field of view of the LASCO coronagraph and COR1, changes only slightly.

We've found that the angular size of CMEs increases 2 - 4 times during the main acceleration phase.

During the main acceleration phase the direction of the CME motion for the 6 events remains practically unchanged. In the LASCO/C2 field of view the deviation of the CME trajectory from its original direction is possible within 20 degrees limits.

The changing CME width to height ratio reflects the influence of forces acting on the CME from different directions. In the case where this relationship ceases to change, we can assume that the CME expands self-similarly.

In four cases this parameter changes slightly during the main acceleration phase.

But in two cases (11.02.2011 and 03.08.2011) the width increases faster than height at the initial stage of CME propagation.

Future Work

We will continue to collect statistical data to check the previously found regularities of CME formation and movement during the initial stage. These regularities include:

(a) The CME forms after the eruption of a filament or another magnetic flux rope.
(b) The initial stage of CME formation is accompanied by the appearance of loop-like structures of high-brightness moving one after another, some of which eventually form the front structure of CMEs.
(c) There is an inverse correlation between the amplitude of CME main acceleration and duration of this acceleration.
(d) The characteristic time scale for the angular size of CME to double during the initial stage of propagation is 5-10 min.
(e) There are variations in CME front edge properties in different spectral channels.
(f) At certain stages the CME moves in a self-similar mode.

It is planned to study the physical mechanisms of correlation between filament eruption and CME formation.

We will attempt to find out what are the differences between the formation of a pulsed CME (CME velocity increases rapidly and the main acceleration phase is relatively short) and a gradual one (slow propagation at a relatively small velocity).

The formation and propagation of shock waves will be investigated by using data radio bursts of type 2, and scanning of brightness ahead of the CME front edge.