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Constraining CMEs and Shocks by Observations and Modelling throughout the inner heliosphere

DURATION
15/12/2016 - 15/03/2021

BUDGET
694 737 €

PROJECT DESCRIPTION

Context

The Sun is the only star where many astrophysical processes can be studied in detail. It is the closest star which enables us to observe its surface activity and immediate consequences in interplanetary space. The outermost layer of the solar atmosphere, the corona, is a dynamic plasma system in which the most energetic transient processes in the solar system, flares and coronal mass ejections (CMEs) occur. CMEs are large amounts of plasma and magnetic flux expelled from the Sun into the interplanetary medium (heliosphere). Magnetic field in CMEs plays the main role in creating disturbed space weather conditions (geoeffective CMEs) by driving geomagnetic storms that may disrupt satellite operations, navigation systems, and radio communications. Studies of CMEs are therefore a key topic in solar physics and space weather research.

The magnetic configuration of a CME close to the Sun is poorly known, and its evolution on the way from the Sun to the Earth depends on a number of factors, including the interaction of the CME with the background solar wind (e.g. deceleration/acceleration, deformation, erosion, shock wave formation). The resulting configuration at 1 AU may include the ICME (interplanetary CME), the shock driven by the ICME, and the sheath region between them. Our knowledge on the CME-ICME structure is poorly constrained by observations and we have to rely on models, which lack some key characteristics in order to provide accurate forecasts of the coronal and heliospheric conditions. In particular, none of the presently available models can predict the magnetic structure of CMEs, the stand-off distance of the associated shock wave, or the properties of associated solar energetic particle events.

General objectives, underlying research questions and methodology

The overarching science question to be addressed in this project is: how do CMEs propagate and evolve through the inner heliosphere? To address this question, the main objectives of the project are: 1) to simulate the propagation of flux rope CME-ICME structures in realistic background solar wind conditions, with the resulting model exceeding the current state of the art, and 2) to compare the results of the model with observations of a number of events of different types.

We will use EUHFORIA (EUropean Heliospheric FORecasting Information Asset), a newly model developed at the KU Leuven and University of Helsinki. We will perform simulations of several typical case study events and produce the arrival times to 1 AU, the strength and direction of the magnetic field in the sheath and the flux rope, the stand-off distance between the shock and the ICME, the brightness of the ICME and the sheath in white light. The derived quantities will be compared with observations, allowing in return a fine-tuning of EUHFORIA.

Nature of the interdisciplinarity

The project combines observational and modeling studies of the Sun and the heliosphere. The project results will be important for geophysical applications.

Potential impact of the research on science, society and/or on decision-making

The scientific impact is about 70 %, and both societal and political impact are about 30 %.

The set-up of EUHFORIA, a realistic numerical code to model the solar wind and CME propagation will provide a large leap in our understanding of the interaction between the CME magnetic field and the background solar wind.

EUHFORIA will be a formidable tool for the Space Weather community. It will significantly improve our awareness of space weather hazards that arise at Earth and it will fit very well within the European Space Agency Space Situation Aweareness program.

The societal impact that will arise from the research in the project concerns the improvement of our space weather forecasting capabilities. Data-driven modeling with EUHFORIA will provide an information on the CME-ICME and associated shock arrival time in the Earth vicinity, and describe the magnetic structure of the CME, which will be sufficient for space weather forecasters to evaluate the risk of a geomagnetic storm in a way beyond the current prediction capabilities.

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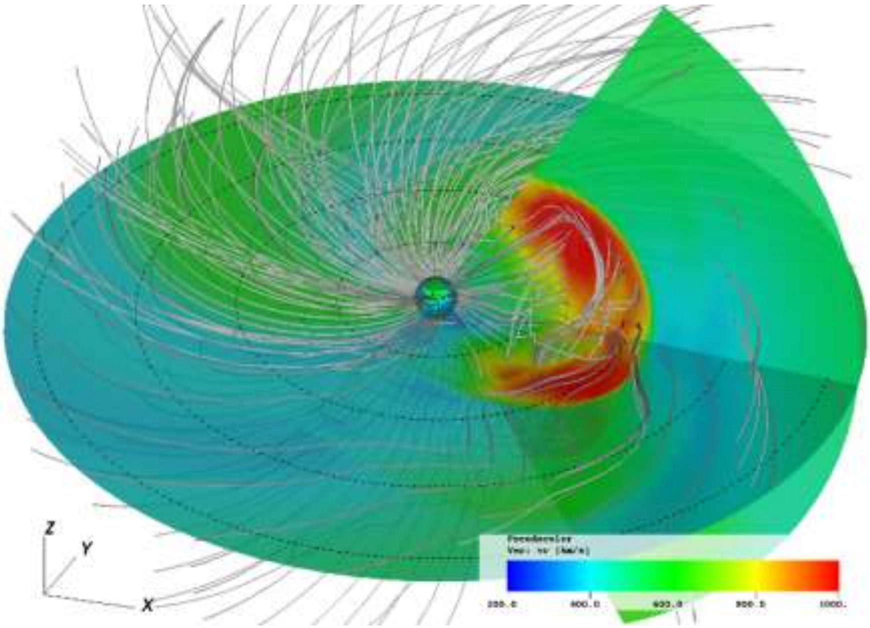
Description of finished products of research at short and medium term

The project will address some of the most intriguing questions in heliophysics and enable us to understand why some CMEs have significant geomagnetic impact although the predictions were indicating differently. As a result of the project we will release three reports at different stages of the developments of EUHFORIA (one in the first year of the project and one report for each version of the EUHFORIA). At least six publications in the scientific journals will follow from the planned studies. At the end of the project EUHFORIA will be tested, fully operational and ready for scientific and forecasting exploitation. It will be set up at ROB for the use in space weather operations of the ISES Regional Warning Center Belgium.

Figure 1. *Three-dimensional view of a snapshot from the EUHFORIA model runs for the June 23, 2015 event that caused a significant geomagnetic storm.*

The colour indicates the radial speed in the ecliptic plane and in the meridional plane containing Earth. The CME is visible as the red area, while green and blue areas show fast and slow solar wind streams, respectively. Grey curves show the structure of the complex magnetic field.



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LINKS

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