SWiM

Solar wind modeling with EUHFORIA for new heliophysics space missions

DURATION
15/12/2019 - 15/03/2024

BUDGET
503 028 €

PROJECT DESCRIPTION

Context

The Sun is our closest star and this proximity enables us to observe readily its surface activity and its effects in the interplanetary space (heliosphere). The solar atmosphere is a dynamic and complex plasma system that expands into the heliosphere as a continuous outflow called the solar wind. The solar wind with its transient structures, such as coronal mass ejections (CMEs), may generate space weather disturbances that can affect human life and especially modern technological society: satellite operations, navigation systems, radio communications, etc. Therefore, research about the solar wind and CMEs is a key topic in solar physics and space weather.

Properties of the solar wind plasma (density, temperature, magnetic field) change on the way from the Sun to the Earth, but this process is poorly constrained by observations. Direct (in situ) measurements have been so far restricted to 1 AU (astronomical unit), which is not sufficient to constrain the evolution of the solar wind and its structures, all the way from the Sun to the Earth. Therefore, we need to rely on models, which are still not realistic enough to predict, with sufficient accuracy, the arrival of high-speed streams (HSS) at the Earth or the magnetic configuration of CMEs.

State-of-the-art models of the solar wind and CME propagation, including EUHFORIA (European Heliospheric Forecasting Information Asset), take as input solar remote-sensing observations. Two new missions, the NASA's Parker Solar Probe (PSP, launched in August 2018), and ESA's Solar Orbiter (launched in February 2020), provide novel in situ observations at different points of the inner heliosphere, ideal for comparison with the modelled results of EUHFORIA.

General objectives and underlying research questions and methodology

The overarching science question to be addressed in the project is: how does solar wind evolve and defines its space weather impact on the Earth? The main specific objectives are: (a) to simulate the background solar wind and CME propagation using EUHFORIA, (b) to compare the simulation results to novel in situ observations by PSP and Solar Orbiter and, (c) to improve and optimize EUHFORIA for scientific and forecasting purposes. To achieve these objectives, the project brings together two world-class research groups in solar physics: CmPA - Katholieke Universiteit Leuven (KUL, expert in modelling) and the SIDC - Royal Observatory of Belgium (ROB, expert in observations and space weather forecasting).

The project will focus on studying in situ observations at different points of the inner heliosphere and on their comparison with the modelled results of EUHFORIA. PSP and Solar Orbiter will provide unique in situ measurements of the solar wind plasma and magnetic field parameters in a wide range of heliocentric distances and heliospheric latitudes. These novel data will be supplemented by in situ observations taken around 1 AU, constituting an unprecedented data set and a strong innovative component to the project. The EUHFORIA modelling will thus be constrained at many heliospheric locations, which will allow its improvements. Two new coronal models will be implemented in EUHFORIA and different setups of EUHFORIA will be validated.

Potential impact of the research

The scientific impact is about 70 %, and societal and political impact are about 15 % each.

The project aims at making a breakthrough in studies of the solar wind and CMEs by combining novel observations and numerical simulations. The planned improvements of EUHFORIA will advance the heliospheric modelling strongly beyond the current state of the art. SWiM will deliver, together with a number of scientific publications, an improved version of EUHFORIA ready for the operational forecasting activities at ROB. The improvement of our space weather forecasting capabilities are the main societal impact. The acquired knowledge will be directly transferred to the team of ROB space weather forecasters, and help improving the quality of predictions. Beyond its scientific use, an improved EUHFORIA will be an excellent tool for the space weather community and it will strongly improve our awareness of space weather hazards. EUHFORIA will also strengthen the Belgian position in the ESA Space Situational Awareness program. We expect that a realistic model like EUHFORIA will bring the space weather community closer to the meteorological community in terms of forecasting capabilities.

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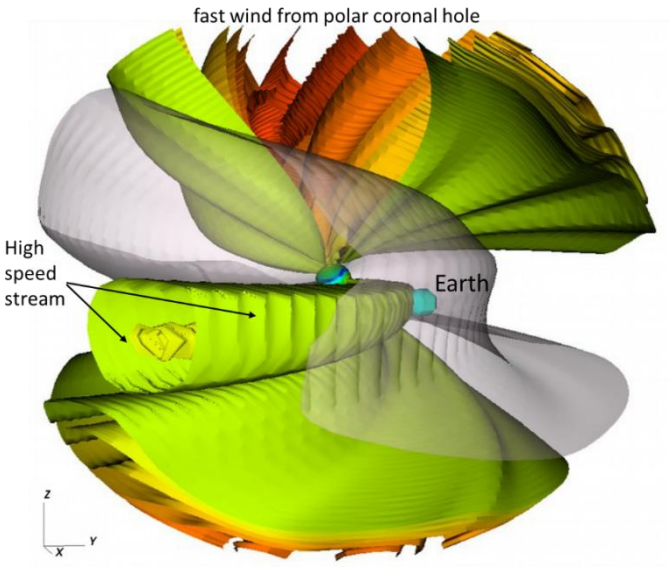
Description of the expected final research results at short and medium term

The SWiM project will address some of the most intriguing questions in heliophysics and enable us to understand how the solar wind evolves, why some high speed streams arrive at Earth and some not, and how the ambient solar wind influences the propagation of CMEs. The project results will be presented in at least six peer-reviewed publications. Three reports at different stages of the developments of EUHFORIA will be released including one on the benchmarks for different versions of EUHFORIA. At the end of the project the improved EUHFORIA will be ready for scientific use and operational space weather forecasts.

Figure 1. Three-dimensional view of EUHFORIA model run showing the arrival of a HSS at Earth on January 21, 2018 (bright green colour). The colourful isosurfaces represent solar wind flows of different speeds. The spherical, inner boundary surface (at 0.1 AU) is in the canter of the domain, and Earth is depicted as a blue sphere.



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LINKS

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