**Coronal Mass Ejections, Workflows and Propagation Models.**

Coronal mass ejections (CMEs) are spectacular eruptions of plasma and magnetic field from the Sun, that carry large amounts of energy through the solar system to interact with the planets in a manner referred to as “space weather” (Prangé et al. 2008?, Webb & Howard CME review 2012?). They are the main driver of the spectacular aurorae often observed in Earth’s atmosphere, but can be of detriment to our technological infrastructure as they interfere with satellite operations, telecommunication and GPS networks, and cause radiation increases for high-altitude or polar airtravel and manned spaceflight missions. To this end, many scientifically-motivated observations of the Sun and CMEs are also useful in a realtime application, to detect and alert us of a CME’s occurrence. An advance-warning system can allow us to undertake preventative measures to minimise the damage of a potentially geoeffective impact at Earth; but this type of system requires an inherent understanding of the physics governing CME propagation in the solar wind, and their evolution through the interplanetary environment, so that an estimated time of arrival (ETA) may be produced.

Numerous CME detection catalogues currently exist in an effort to provide realtime alerts to the space weather community. Similarly a variety of theoretical CME and solar wind models have been built to take input from the remote-sensing observations and/or in-situ measurements, and simulate CME propagation through the relevant portions of the solar system. Predicting the ETA of a CME therefore requires the use of observational data, an understanding of CME and solar wind propagation theory, and the computational resources necessary to promptly model and predict their evolution through space. Observational data exists in the form of telescopic imagery from such missions as the Solar & Heliospheric Observatory (SOHO; Domingo ref?) launched in 1995, and the more recent Solar Dynamics Observatory (SDO; ref?) launched in 2010. From the image data provided by such missions, various CME properties may be determined, such as the start-time and location, and early-stage kinematics and morphology. These properties are then used in a propagation theory that normally considers some form of ballistic motion of the CME on top of a simplified magnetohydrodynamic (MHD) treatment of its evolution and interaction with the solar wind. Details on the current CME models in use/development may be found in, e.g., ENLIL ref, HAFv2 ref, ISPM ref, or STOA ref, with each determining its own predicted arrival time of the bulk CME material and/or associated shock.

Research is ongoing into the effects of solar wind drag that can act on CMEs; with the general result that fast CMEs are slowed down, and slow CMEs sped up, to the surrounding solar wind speed (Maloney et al 2009?). Different models generally quantify this effect in different ways, and can therefore produce varying predictions on CME propagation and evolution. In-situ data is often used as a validity check on the results of a CME model run, by comparing the predicted and observed arrival time of a CME and/or shock, and examining the parameters that may be responsible for any sources of error. Thus the model parameters may be iterated to an input that most appropriately simulates the true CME evolution, and the model itself adjusted for improved future performance.

Performing such iterations over multiple case-studies may be made substantially easier through the introduction of a workflow type process. This is especially true when one considers that the SOHO/LASCO instrument has observed >10^4 CMEs since launch, and extensive catalogues built from the resulting metadata both human users and automated algorithms have produced. Furthermore, a wealth of similar data exists in catalogues of other solar phenomena, such as flares, filaments, coronal holes, and shocks. In order to utilise all such event information in tandem, we use the Helio Event Catalogue (HEC) that is a compilation of all current solar activity catalogues. The main interaction with the HEC is primarily through web services. Our approach is to construct workflows and graphical user interfaces that involk these web services, parse the responses and use the vast amounts of metadata in the HEC to construct propagation models of CMEs. This allows us to test the physical validities of CME propagation theory and check the reliability of the metadata for use in CME physics.

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**The workflow**

The general approach is to use workflows and GUIs to interact with the metadata conatined in a variety of catalogues of solar eruptive events. We first check a CME catalogue to determine time of eruption and velocity. These properties are use to propagate the CME forward to determine an ETA. The actual time of arrival is then obtained from catalogues of in-situ measirements e.g., sensors in orbit around Earth. Comparing the ETA and the actual arrival time will then allow us to check the validity of the propagation model (or the parameters used to run the model).

The GUI allows the user to easily change components of the workflow depending on the desired catalogue to query, or what kind of propagation model is chosen e.g., purely ballistic or a aerodynamic drag-based model.

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**Scientific Use Cases;**

**-Radio Bursts and Shock Arrival Times**

-CMEs ability to drive shocks

-Type II radio bursts

-Relating radio shock signature to in-situ shock signature at various locations on the heliosphere

-To what distance into the heliosphere is a CME shock maintained?