Improving Space Weather Forecasting With EUV Observations. Leon Golub, Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138.

Introduction: Accurate predictions of harmful space weather effects are mandatory for the protection of astronauts in lunar orbit or on the surface of the Moon. Observation of the solar corona from earth orbit or from other locations such as L1 or L5 using suitably-chosen EUV wavelengths offers the possibility of addressing two major goals that will improve our ability to forecast and predict geo-effective and seleno-effective space weather events: 1.) improve our understanding of the coronal conditions that control the opening and closing of the corona to the heliosphere and consequent solar wind streams, and 2.) improve our understanding of the physical processes that control the early evolution of CMEs and the formation of shocks from the solar surface out to beyond the nominal source surface.

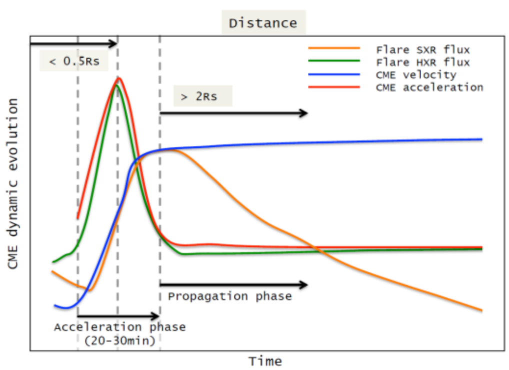

Figure 1. For a typical CME, early detection of location, direction, acceleration and magnetic structure [1] are crucial input to forecast models.

Need for Early Detection: Forecasting models such as EUHFORIA find that predictions at 1 au are extremely sensitive to the initial conditions input to the model [2], and significant changes in magnetic field orientation, magnetic topology and CME direction, plus the main acceleration phase of the CME, all occur in the low and middle corona (Figure 1). EUV imaging plus spectroscopic imaging data can determine 8 of the 10 kinematic parameters used in forecast models.

EUV measurements can help to: i.) determine coronal structuring from its roots out to beyond 2.5 R_s; ii.) measure the changes in coronal connectivity; iii.) distinguish between and test solar wind models; iv.) establish the impact of pre-existing coronal structures on CME evolution; v.) confront theories of SEP acceleration and preconditioning; and vi.) establish the extent of energy release behind CMEs.

The Multithermal Corona: The time-varying solar corona is structured both in space and in temperature (Figure 2), making the observations effectively five dimensional. A method for efficiently observing multiple wavelengths simultaneously is therefore desirable. This is especially necessary for CME observations, as the departing magnetized plasma shows markedly different structures at different temperatures and even the detectability of the event varies dramatically at different EUV wavelengths (Figure 3) [3].

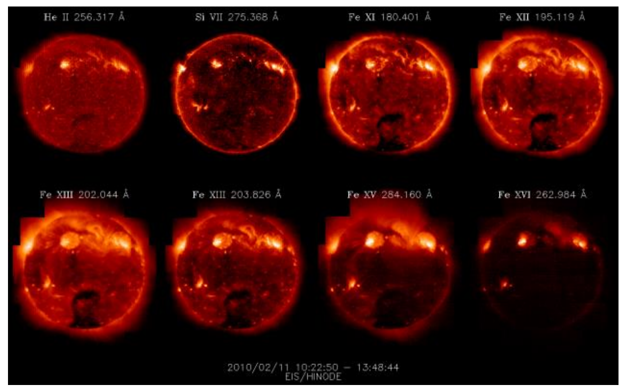

Figure 2. The EUV corona is multi-thermal, with different portions of the atmosphere visible in different spectral lines, depending on their temperature of formation.

This multithermal observational requirement is seen as an advantage when we realize that portions of the erupting CME at different temperatures evolve differently and cause different space weather effects.

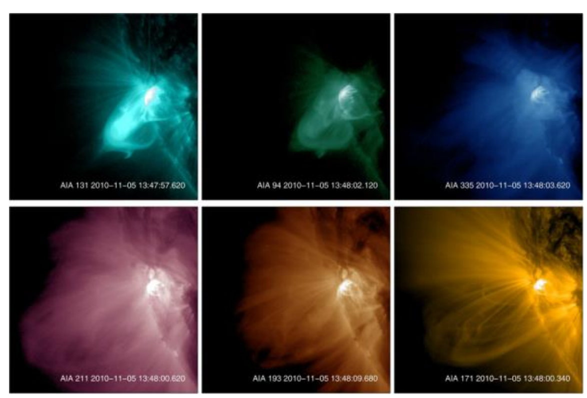

Figure 3. CMEs are multi-thermal in the EUV, revealing markedly different components at 15MK (13.1nm), 9 MK (9.4nm), 3MK (33.5nm), down to He II 30.4nm, not shown) at ~0.1MK.

Instrumentation: The usefulness of wide-field EUV imaging for CME detection has gained wide acceptance following the results from instruments such as SDO/AIA, SWAP and GOES-R/SUVI [4].

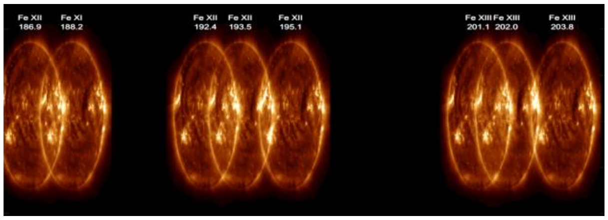

Figure 4. A slitless spectrograph operating in the EUV allows efficient detection of multiple full disk coronal images over a range of wavelegths simultaneously in a single observation.

However, the multithermal nature of the target regions argues that wavelength separation is also needed. The temporal limitation imposed by a single-slit imaging spectrograph can be overcome by using a multi-slit instrument [5]. Alternatively, a slitless imaging spectrometer can be used (Figure 4). In both cases, the problem of separating overlapping portions of the data into their correct wavelength bins has been effectively solved [6].

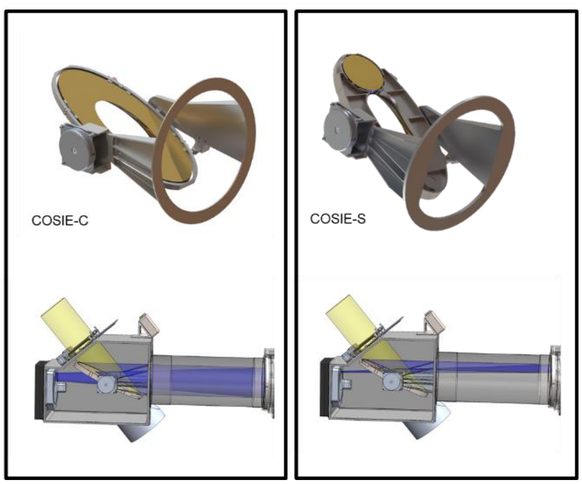

Figure 5. The COSIE instrument design combines a sensitive wide-field EUV imager and a slitless full-disk imaging spectrometer in a compact design.

A fairly simple instrument of moderate size (Figure 5), located in Earth orbit, Sun-synchronous LEO or GSO, or at L1 or L5, or in lunar orbit, would provide suitable observing capability. Working closely with forecast modelers to make full use of the data is crucial, working first in a research mode, then operationally.

References: [1] Temmer et al. [2] Verbeke et al. [3] Reeves, K. and Golub, L. (2011) ApJL, 727, L52 [4] West, M.J., et al. (2019) 2019shin.confE.105W; Seaton, D.B. and West, M.J. (2019) shin.confE..83S; Tadikonda, S.K., et al. (2019) SolPhys, 294, 28; [5] DePontieu, B. et al. (2020) ApJ, 888, 3; [6] Cheung, M. et al (2019) ApJ, 882, 13, Winebarger, A. et al. (2019) ApJ, 882, 12.