Proba-2 Guest Investigator Program
Final Report

David Long
TCD/MSSL

This report serves as a summary of my SWAP Guest Investigator placement at the Royal Observatory in Belgium (ROB) undertaken between 21 Nov. and 16 Dec. 2011. A summary is given of the proposed science objectives along with an overview of the actual placement and any proposed follow–up work to achieve the aforementioned proposals.

The science objectives for this placement were to investigate the relationship between the on–disk "EIT wave" and the erupting Coronal Mass Ejection (CME) associated with it. CMEs are spectacular eruptions of plasma that propagate outwards from the Sun into the heliosphere and are often associated with solar flares and disturbances that propagate across the solar surface at very high velocities. These disturbances are called "EIT waves" and remain a source of investigation, particularly with regard to the exact nature of their relationship to CMEs. This issue remains unresolved due to the lack of very high cadence observations of the initial stages of a CME eruption; EUV imagers tend to have a Sun–centred, maximum field–of–view of $\sim$1.6 $R_{\odot}$, while the field–of–view of coronagraphs tends to begin at $\sim$1.4 $R_{\odot}$. This relatively small degree of overlap allied to a relatively low observing cadence makes it difficult to match on–disk EUV images and off–disk coronagraph observations, complicating analysis of eruptive events.

To investigate this relationship, it was proposed that the combination of the very large field–of–view of SWAP and off–pointing capabilities of the *Proba–2* spacecraft would be used to examine the initial stages of a CME eruption. By off–pointing the spacecraft, it would be possible to track the initial propagation of the CME into the heliosphere, while simultaneously examining the on–disk propagation of the "EIT wave" pulse by retaining the Sun within the field–of–view of the instrument. These off–pointed images would then be combined with very high cadence images from the *Solar Dynamics Observatory* spacecraft, allowing a thorough analysis of the properties and morphology of the "EIT wave" pulse as it propagates across the visible disk.

Upon arrival at the ROB, the first issue was to determine the capabilities of SWAP when dealing with off–pointed images. In particular, the intensity of the corona drops off dramatically with height, with the result that it can be difficult to discern structures in the outer corona using EUV emission. To overcome this issue involves extensive image processing, including image summing, where a number of images over a given time range are combined to increase the signal–to–noise at larger distances from the Sun.

While this approach does increase the image intensity and improve the clarity of off–disk structures, there are caveats. The combination of more images naturally increases the intensity, but at the risk of removing transient structures and motion. Off–pointed SWAP images from 2011 August 9 were used to examine the optimum number of images required to improve image intensity in the outer corona while retaining the ability to

identify rapid motion. As a result of this analysis, it was decided that 3–4 images were required for future work.

The next issue involved the combination of data from the Atmospheric Imaging Assembly (AIA) instrument onboard *SDO* with data from SWAP. This was complicated by the difference in spatial resolution between AIA and SWAP as well as the off–pointed nature of the SWAP images. However, it was possible to produce an algorithm that combines both sets of data, allowing the initial evolution of the CME eruption to be tracked to a greater distance than previously possible while retaining the native cadence of both data–sets.

Once the issues with regard to the off–disk intensity variation had been resolved and a technique developed to allow direct comparison of AIA and SWAP data, the next step was to develop an observing plan to obtain scientific quality data. The observing plan involves off–pointing *Proba–2* sufficiently to retain the whole Sun in the field–of–view. The images taken by SWAP are rebinned onboard the spacecraft from 1024×1024 to 512×512 pixels, with a nominal cadence of ∼20 s. The images are then ranked, with the first three images given highest priority, the fourth given a medium priority and the fifth given lowest priority. This image ranking ensures that when the onboard memory limit has been reached, the lowest priority images are overwritten first, with the result that there is typically a burst of three or four images that can be combined to produce a single high intensity image with a nominal cadence of ∼100 s. This setup ensures high cadence, high intensity observations that allow the identification of faint coronal structures further from the solar surface.

This observing plan was initially run on 2011 December 7 to determine its viability and to check the quality of the resulting data. It was decided that the test data produced was of a sufficiently high quality to allow detailed scientific analysis of future events. As a result, this observing plan was added to the list of SWAP observing plans and may be invoked at any time upon consultation with the spacecraft operators at ROB.

Future work involves the observation of a CME eruptive event using this plan and analysis of the resulting data. Due to the random nature of "EIT waves", it will be necessary to identify a promising active region in advance and observe it for a period of ∼24 hours using SWAP. Through continuous examination of data from *STEREO*–B, it is hoped to identify a promising active region in the very near future. Once a sufficient data–set has been obtained, the next step is the analysis and eventual publication of the event. It may also be necessary to return to ROB for a very brief visit to allow close collaboration with the SWAP team once this data has been obtained, although this is predicated on the identification of a suitable data–set.