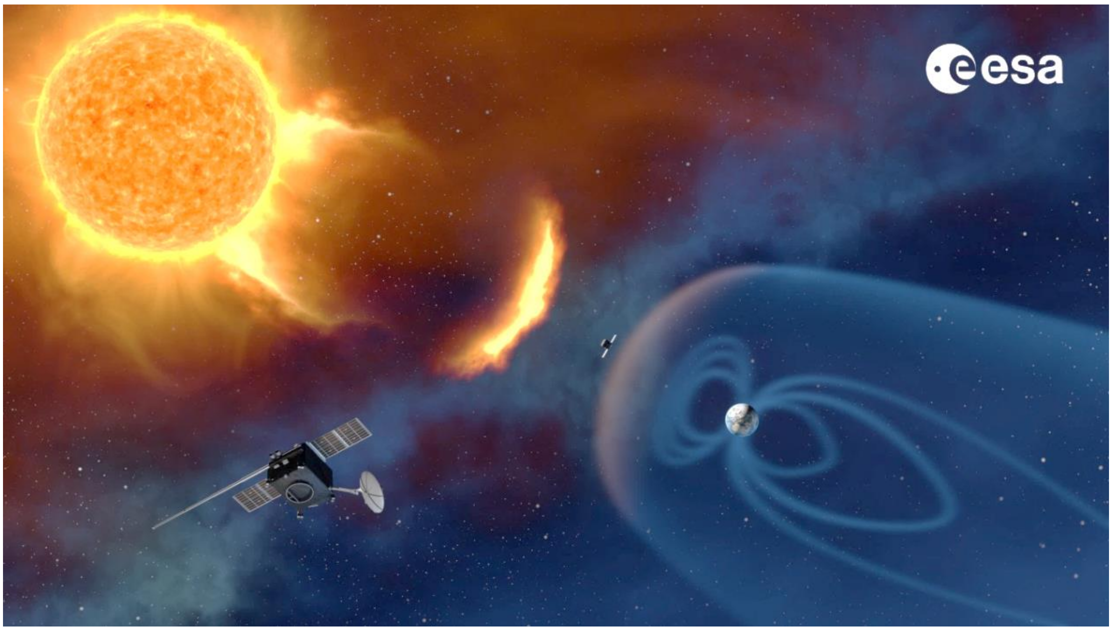
RAS Discussion meeting (G) – 8th March 2019

Transitioning Research and Instrument Expertise in Heliophysics into Space Weather Monitoring Capabilities at L1 and L5



[credit ESA]

The UK has a world-class heliophysics programme in terms of both research and the underpinning instrumentation; this is illustrated by scientific missions such as SOHO, Cluster, STEREO and Solar Orbiter. Investment in these missions has resulted in major advances in our understanding of the physics of our solar system. This experience is crucial for understanding the "space weather" effects of solar-generated activity on human technology and health. Since the UK Government placed extreme space weather on the Risk Register of Civil Emergencies in 2011, the UK has been at the forefront of endeavours to develop an effective approach to space weather mitigation. This includes: establishment of the Space Environment Impact Expert Group to advise Government; formation of the UK Met Office Space Weather Operations Centre; engagement with ESA's SSA Space Weather programme. The aim of the latter is to launch an operational space weather monitoring mission to the L5 Lagrange point, in conjunction with a US mission to L1. To this end, Phase A/B1 studies of the L5 spacecraft and payload are underway. Both the remote-sensing and in-situ instrument package studies (and one of the parallel system studies) are being led by the UK. It is, hence, timely to assess how best to coordinate the complementary research and operational aspects of the UK's heliophysics programme. This discussion meeting is aimed at the transitioning of research and instrumental expertise acquired from our recent and on-going space science missions into operational space weather capabilities.

Organisers:

Professor Richard A Harrison[1], Dr Jackie A Davies[1] and Dr Jonny Rae[2]

1. STFC RAL Space, Harwell Campus, Didcot, Oxfordshire OX11 0QX
2. Mullard Space Science Laboratory, Holbury St Mary, Dorking, Surrey

E-mail - richard.harrison@stfc.ac.uk

Location:

Lecture Theatre, RAS, Burlington House

Programme

10:00 Tea/coffee available in the RAS Library (Posters to be displayed in the Library)
10:30 Welcome/introduction

Part 1: ESA's space weather programme and the Lagrange mission [Chair: Richard Harrison]

10:35-11:00 ESA's space weather programme, J.-P. Luntama (ESA Space Safety Programme) [Invited talk]

11:00-11:12 The remote sensing package for the Lagrange Mission, J.A. Davies (RAL Space) and the Lagrange Remote Sensing Consortium

11:12-11:24 In-situ environment monitoring by space weather missions to the Sun-Earth Lagrange points, J. Rae (Mullard Space Science Laboratory), on behalf of the In-situ Lagrange Team

11:24-11:36 Magnetic field measurements at L5 and development of the Lagrange magnetometer, J.P. Eastwood, C. M. Carr, C. Palla (Imperial College London) and W. Magnes, G. Berghofer, A. Valavanoglou, R. Nakamura, C. Moestl (IWF Graz)

11:36-11:48 Spacecraft design for space weather monitoring from L5, T. Harris (Airbus Defence and Space Limited)

Part 2: UK space weather strategy [Chair: Jonny Rae]

11:48-12:13 The UK's space weather operations centre, M. Gibbs (Met Office) [Invited talk]

12:13-12:25 Space Weather in the UK: National Priorities and Contributions to the International Space-Weather Capability and Strategies, M.M. Bisi, M.A. Hapgood and R.A. Harrison (RAL Space), M. Gibbs and C. Burnett (Met Office), and M. Willis (UKSA)

12:25-12:37 Solar wind modelling at the Met Office – towards exploitation of L5 data, E. Henley, S. Gonzi and D. Jackson (Met Office)

Part 3a: Science and instrumentation [Chair: Jonny Rae]

12:37-12:57 Improving Space Weather Forecasting With Wide-Field EUV Observations, L. Golub (Harvard-Smithsonian Center for Astrophysics) [Invited talk]

13:00-14:00 LUNCH (and poster viewing)

Part 3b: Science and instrumentation [Chair: Jackie Davies]

14:00-14:12 Impact of an L5 Magnetograph on Nonpotential Solar Global Magnetic Field Modelling, D.H. Mackay (University of St Andrews), A.R. Yeates (University of Durham) and F.X Bocquet (Met Office)

14:12-14:24 In-situ solar wind data assimilation from L5, M. Owens and M. Lang (University of Reading)

14:24-14:36 L1/L5 observations and Solar Energetic Particle events, T. Latinen, S. Dalla (University of Central Lancashire)

14:36-14:48 Using Ghost fronts within STEREO Heliospheric Imager data to infer the evolution in longitudinal structure of a Coronal Mass Ejection, C. Scott and M. Owens (University of Reading), Curt de Koning (NOAA SWPC), Luke Barnard, Shannon Jones and Julia Wilkinson (University of Reading)

Part 3c: Science and instrumentation [Chair: Richard Harrison]

14:48-15:00 The evolution of an Interplanetary Coronal Mass Ejection: ACE/WIND, THEMIS B/C and Juno Observations, E. Davies (Imperial College London)

15:00-15:12 SAMNet - Solar Activity Monitor Network - A ground-based network to support space weather prediction, R. Erdelyi and the SAMNet Team (University of Sheffield)

15:12-15:24 Timescales of Birkeland currents driven by the IMF, J.C. Coxon (University of Southampton), R.M. Shore and M.P. Freeman (BAS, Cambridge), R.C. Fear, S.D. Browett, A.W. Smith and D.K. Whiter (University of Southampton), and B.J. Anderson (Johns Hopkins University Applied Physics Laboratory)

POSTERS (Viewing times: 10:00-10:30 [tea/coffee], Lunch and afterwards)

SULIS: Solar cUbesats for Linked Imaging Spectropolarimetry, Eamon Scullion (Northumbria University), Huw Morgan (Aberystwyth University), Haosheng Lin (IfA, University of Hawaii), Jackie Davies and Richard Harrison (RAL Space)

Space weather monitor at the L5 point: a case study of an interplanetary propagation of a CME observed with STEREO B, M. J. West, L. Rodriguez, C. Scolini and M. Mierla (ROB)

Mapping low corona flow trends via time dependent AIA image processing, Gabriel Muro, Huw Morgan (Aberystwyth University)

Simultaneous Rotational Analysis of Complex Multi-Spot Sunspot Groups, R. Grimes (University of Aberystwyth)

A study of fan-shaped jets within a flaring Active Region using IRIS, L. Humphries (University of Aberystwyth)

A consideration of the multi-viewpoint and single-viewpoint exploitation of heliospheric imaging in light of over a decade of operation of the STEREO/HI instruments, R.A. Harrison and J.A. Davies (RAL Space)

<u>ABSTRACTS</u>

ESA's Space Weather Programme

Juha-Pekka Luntama
Space Weather Office, ESA Space Safety Programme

European Space Agency's (ESA) Space Situational Awareness (SSA) Programme has been developing since 2009 the European Space Weather (SWE) System for the capability to provide operational space weather services to support protection of European space and ground based assets against adverse effects from space weather. This system is based on use of European space weather assets through a federated network consisting of thematic Expert Service Centres (ESCs) and SSA Space Weather Service Coordination Centre (SSCC). Many European space weather centres of excellence in academia, research institutes and industry are already part of the network and inclusion of additional groups in the framework of coming ESA space weather activities. In parallel, SSA Programme has been developing European space weather monitoring capability.
This presentation will address the status and achievements of the space weather activities in the framework of ESA's SSA Programme and show the prospects for the coming activities and developments after 2020 when the Programme will evolve into Space Safety Programme with expanded scope and additional objectives.

The Remote-Sensing Package for the Lagrange Mission

J.A. Davies & the Lagrange Remote-Sensing Consortium
RAL Space

The space weather element of ESA's SSA programme was established to address the increasing risks of solar effects on human technological systems and health. Within its current Period 3, the SSA programme has been extended to include the additional Lagrange (LGR) element, targeted towards the development of an operational space weather mission to the L5 Lagrange point. Under the auspices of LGR, a number of Phase A/B1 studies are well underway; these studies cover the remote-sensing payload, the in-situ payload, and the overall system. Here, we review the status of the Phase A/B1 study of the remote-sensing instrument package, which includes a Photospheric Magnetic Field Imager (PMI), EUV Imager (EUVI), Coronagraph (COR) and Heliospheric Imager (HI). We will review the current instrument designs, including the instrument control and processing philosophy (in terms of a shared Instrument Processing and Control Unit, IPCU, albeit in conjunction with a dedicated PMI processor); we will also present the progress towards defining the baseline architecture for the End-to-End simulator for the whole instrument package.

In-situ environment monitoring by space weather missions to the Sun-Earth Lagrange points

Jonathan Rae, on behalf of the In-situ Lagrange Team
Mullard Space Science Laboratory

In-situ monitoring of the magnetic, plasma and radiation environment of interplanetary space is essential for any advanced space-weather early warning system. Near real-time measurements from well-chosen locations are extremely valuable in alerting satellite operators and utility providers on Earth when there is an increased risk of hazards from geomagnetic storms and other space weather effects.

Space weather causes of interest include, but are not limited to, high speed solar wind streams, stream interaction regions, solar energetic particle events and interplanetary coronal mass ejections. Towards this goal, the European Space Agency initiated assessment studies for space weather monitoring missions to the L1 and L5 Solar Lagrangian points within its Space Situational Awareness (SSA)Programme.

Phase A/B1 studies are now well underway on space weather monitoring from an L5 mission. In order to provide effective forecasts and warnings, such missions must carry an in-situ instrument suite to measure the energetic particle environment, bulk solar wind conditions, solar X-ray emissions and the interplanetary magnetic field.

We discuss science and measurement requirements for space weather monitoring missions at L1 and L5, including operational needs and key challenges for reliable in-situ environment monitoring. We also highlight the value of joint measurements at both L5 and L1 for improving existing models of the inner heliosphere that will, in turn, improve space weather prediction capabilities. Finally, we will present a brief overview of the types of instruments and techniques available for such a mission.

Magnetic field measurements at L5 and development of the Lagrange magnetometer

J.P. Eastwood, C. M. Carr, C. Palla
Imperial College London
W. Magnes, G. Berghofer, A. Valavanoglou, R. Nakamura, C. Moestl
IWF Graz

Phase-0 studies for the ESA L5 space weather mission 'Lagrange' have deemed in situ measurement of the magnetic field as mandatory to meet the operational requirements of the mission. Knowledge of the magnetic field strength and orientation is crucial for understanding the geoeffectiveness of large-scale structures in the solar wind such as coronal mass ejections and stream interaction regions. Furthermore, magnetic field data is required to understand energetic particle propagation and the connectivity of the solar wind back to the corona. It will also be a crucial element of next-generation solar wind and magnetosphere models that rely on data assimilation.

Imperial College London and IWF Graz are developing the magnetometer for the Lagrange mission, and here we describe the instrument heritage, concept and current status. The instrument is derived from science missions such as JUICE, Solar Orbiter, MMS, Bepi Colombo, DoubleStar and Cluster. The instrument concept is therefore low-risk and high-heritage, using dual flux-gate sensors mounted on a boom to measure the magnetic field. We compare and contrast the magnetic requirements of science vs. operational missions, which are different because operational services require low latency, high reliability measurements. Finally, the current status of the instrument is described.

Spacecraft Design for Space Weather Monitoring from L5

Tim Harris
Airbus Defence and Space Limited

Airbus has been requested by the European Space Agency to design a spacecraft to take a suite of 10 instruments to the Sun – Earth Lagrangian Point 5, due for launch in 2025. From this location the spacecraft will observe the Sun directly, the Solar wind and the region of space between the Sun and the Earth in order to facilitate the early warning of significant space weather events before they affect the Earth and its infrastructures.

The spacecraft must provide an ultra-stable platform with stringent pointing requirements for both the instruments and a continuous data downlink to Earth from a distance of 1AU. The communications architecture includes both an RF system as well as a deep space optical communication system. The accommodation of the instrument suites must allow for over 15 different fields of view, a tightly controlled EMC and magnetic environment and very high levels of molecular and particulate cleanliness. As this mission is operational, near 100% availability must be achieved throughout the whole mission, including during high radiation Solar flare events.

The UK's Space Weather Operations Centre

Mark Gibbs
Met Office

Met Office Space Weather Operations Centre (MOSWOC) has been in continuous 24/7 operations since April 2014. My presentation will focus on what we do, for whom and how we do it. The external requirements on the global space weather enterprise is changing and it is important to recognise what this change means for everyone involved. Then the focus will fall upon expectations on MOSWOC from UK Government and Critical National Infrastructure operators in terms of forecasting the potential for severe geomagnetic storm identifying where L1 & L5 data are important. I will address how the data could be used now and how we envisage data may be used in the future.

Space Weather in the UK: National Priorities and Contributions to the International Space-Weather Capability and Strategies

Mario M. Bisi[1], Mike A. Hapgood[1], Richard A. Harrison[1], Mark Gibbs[2], Catherine Burnett[2], Mike Willis[3]
1 RAL Space, 2 Met Office, 3 UK Space Agency

For several years, UK Government has included "Severe Space Weather" on its National Risk Register of Civil Emergencies leading to a somewhat co-ordinated, wide-ranging set of investigations to tackle its threats at a national level, as well as incorporating active engagement/leadership on the international/global scene. Such investigations address different classes of activity and impacts (e.g. everyday space weather, 1-in-10-, 1-in-30-, and 1-in-100-year space-weather-event scenarios). These not only look at the science, monitoring, modelling, and forecasting capabilities (and their gaps), but they also probe the socio-economics and the UK and wider impacts (including knock-on effects by another region being impacted).

Two immediate responses to the UK Government's engagement in managing its space-weather risk were:
(a) Forming the Space Environment Impacts Expert Group (SEIEG) – a group of independent national experts who provide advice to government; and
(b) Setting up of a UK space-weather forecasting centre at the Met Office – only one of two civil forecasting centres worldwide that offer manned 24/7 operations.

UKSA is responding to these activities and is actively engaging with key institutes. It has become a major supporter of the emerging ESA SSA space weather and Lagrange programmes that has ultimately ensured UK leadership roles in instrument-/mission-development for the planned Lagrange L5 space-weather mission as well as in service activities such as the Heliospheric Expert Service Centre. In addition, the UK has taken a lead on several other space-/ground-based space-weather endeavours that are proving highly complementary to current UK and global capabilities. This is key so as not to overly compete where resources are limited across the board.

All of these activities are a result of active partnerships and extensive dialogue between agencies, industrial groups, the science community, UK Government, and internationally (e.g. ESA, NOAA, NASA, SANSA, ISES, COSPAR, UN COPUOS, etc…) to ensure that the wide range of issues involved are covered.

We provide an overview of the above with any updates from the current SEIEG space-weather scenario definition activities, and look at how and where such these various activities fit into the global effort of improving our understanding and forecast of space weather and its impacts as we work collectively (and internationally) towards the future L5 and L1 space-weather missions.

Solar wind modelling at the Met Office – towards exploitation of L5 data

Edmund Henley, Siegfried Gonzi and David Jackson
Met Office

At the Met Office we run two operational solar wind prediction models, a simple recurrence model and WSA Enlil. Both model forecasts will benefit from observations at L5. We show that the recurrence model produces improved forecasts at L1 when the model is driven by STEREO data close to L5 rather than by data from L1. This benefit is likely to also be shown if we replace the STEREO data with in-situ solar wind data from a future L5 mission. WSA Enlil is run in both deterministic and CME ensemble mode. Previous studies have shown that the estimate of CME initial conditions included in WSA Enlil is poorer when only coronagraph data from L1 is used and STEREO observations (usually made away from the Sun to Earth line) are omitted. Here we show results from a new study where heliospheric imager (HI) data are used to estimate the CME initial conditions in addition to coronagraph data. This approach allows for the pruning of less accurate members of the CME ensemble and this would be an excellent way of exploiting HI data from a future L5 mission to improve operational forecasts. We are also trialling replacing WSA with the DumFric model as the means by which the inner boundary conditions for Enlil are generated. The magnetofrictional approach used in DumFric means that the evolution of the coronal magnetic field should be better represented, and this is an excellent framework for utilising magnetographs from L5 in addition to the existing L1 magnetographs. Finally, we summarise work done by colleagues at Reading and Paris which demonstrates the power of assimilating in-situ solar wind data to improve the representation of the heliosphere. The potential of this approach for assimilating L5 data into Enlil is clear.

Improving Space Weather Forecasting With Wide-Field EUV Observations
Leon Golub
Harvard-Smithsonian Center for Astrophysics

Observation of the solar corona from L5/L1 using suitably-chosen EUV wavelengths offers the possibility of addressing two major goals that will improve our ability to forecast and predict geoeffective space weather events: 1.) improve our understanding of the coronal conditions that control the opening and closing of the corona to the heliosphere, and 2.) improve our understanding of the physical processes that control the evolution of CMEs and the formation of shocks from the solar surface out to beyond the nominal source surface. Forecasting models such as EUHFORIA find that predictions at 1 au are extremely sensitive to the initial conditions input to the model, and EUV imaging plus spectroscopic imaging data, such as that proposed by the COSIE investigation, can determine 8 of the 10 parameters used. This combination of 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.

Impact of an L5 Magnetograph on Nonpotential Solar Global Magnetic Field Modeling
D.H. Mackay[1], A.R. Yeates[2] and F.X Bocquet[3]
1 University of St Andrews, 2 University of Durham, 3 Met Office

We present a theoretical study to consider what improvement could be obtained in global nonpotential modeling of the solar corona if magnetograph data were available from the L5 Lagrange point, in addition to from the direction of Earth. To consider this, we first carry out a “reference Sun” simulation over two solar cycles. An important property of this simulation is that random bipole emergences are allowed across the entire solar surface at any given time (such as can occur on the Sun). Next, we construct two “limited data” simulations, where bipoles are only included when they could be seen from (I) an Earth-based magnetograph and (II) either Earth- or L5-based magnetographs. The improvement in reproducing the reference Sun simulation when an L5 view is available is quantified through considering global quantities in the limited data simulations.

These include surface and polar flux, total magnetic energy, volume electric current, open flux, and the number of flux ropes. Results show that when an L5 observational viewpoint is included, the accuracy of the global quantities in the limited data simulations can increase by 26%-40%. This clearly shows that a magnetograph at the L5 point could significantly increase the accuracy of global nonpotential modeling and with this the accuracy of future space weather forecasts.

In situ solar wind data assimilation from L5

Mathew Owens and Matthew Lang
University of Reading

In order to forecast space weather, it is necessary to accurately predict the solar wind conditions in near-Earth space. At present, remote observations of the photospheric magnetic field are used to constrain coronal and heliospheric simulations. This is able to capture steady-state solar wind conditions. Transient structures resulting from coronal magnetic ejections are incorporated in an ad-hoc manner using speed and size estimates from coronagraph imagers. The heliospheric simulation then propagates conditions all the way from the Sun to Earth, without any further observational constraints. But spacecraft also make direct measurements of the solar wind, which provide useful additional information that is not presently used. We use a simple solar wind model to develop a method to routinely “assimilate” in situ spacecraft observations into the model and thus improve space weather forecasts. This data assimilation (DA) approach closely follows that of terrestrial weather prediction, where DA has led to increasingly accurate forecasts. We particularly focus on data from the STEREO spacecraft when they were separated from each other and Earth at angles similar to an L5 mission.

L1/L5 observations and Solar Energetic Particle events

Timo Laitinen, Silvia Dalla
University of Central Lancashire, Preston, UK

Solar Energetic Particle (SEP) intensities during an SEP event are known to vary both event-to-event and at different locations in space. The variability of the intensities can be attributed to spatial and temporal evolution of SEP acceleration, and to SEP propagation in the interplanetary space. The latter is affected by solar wind turbulence, which causes the particles to scatter along the field lines, and spread across the mean field along meandering field lines, as well as drift across the mean field due to the large-scale Parker spiral structure. In addition, the observations, typically at 1 AU, are made with spacecraft that move with respect to the SEP source: in 4 days the SEP source at the Sun will have ~60 degrees relative to the observing spacecraft. These factors make forecasting SEP events and their effects at Ã‰art a complicated task

In this talk, we discuss the benefits that the proposed L5 mission, in combination with near-Earth spacecraft at L1, can offer for observations, interpretation and forecasting of SEP events and their influence. We find that the SEP time-intensity morphology varies with observer location due to corotation, thus a steady two-point view will greatly reduce uncertainty on for example fluence estimates. L5/L1 observations, in particularly anisotropy observations, will help constrain the transport effects of SEPs from their sources, as well as the transport processes in play. An important contribution to SEP observation analysis is a multipoint measurement of solar wind turbulence, which will enable us for the first time to consistently approach the longitudinal dependence of SEP transport parameters. We discuss the requirements for instrumentation and datasets.

Using Ghost fronts within STEREO Heliospheric Imager data to infer the evolution in longitudinal structure of a Coronal Mass Ejection

Chris Scott1, Mathew Owens1, Curt de Koning2, Luke Barnard1, Shannon Jones1 and Julia Wilkinson1
1 University of Reading, 2 NOAA Space Weather Prediction Center

Images of coronal mass ejections (CMEs) from the Heliospheric Imager (HI) instruments on board the STEREO spacecraft frequently contain rich structure. Here, we present analysis of the Earth-directed CME launched on 12 December 2008 in which we intepret the revealed structure as projections of separate discrete sections of the physical boundary of the CME. By comparing the relative position of the outer and inner 'ghost' fronts seen in the STEREO HI1 cameras with the positions of features determined from three CME models we show that the two fronts seen in the images correspond to the expected position of the flank and nose of the CME where the background solar wind is uniform. In contrast, the flank of the CME observed expanding into a structured background solar wind results in the elongation between the two fronts being greater than expected. This is consistent with the CME flank distorting in the presence of a high-speed solar wind stream. Further work is required to consolidate these results. The presence of a shock for this event was ruled out by consideration of the low CME speed and by studying in-situ spacecraft data. The CME flank crossing the Thomson sphere was also ruled out as a cause of the ghost fronts. Ghost fronts could provide information about the longitudinal shape of the CME independent of geometric models. This information could be used to improve space weather forecast models through techniques such as data assimilation.

The Evolution of an Interplanetary Coronal Mass Ejection: ACE/WIND, THEMIS B/C and Juno Observations.

Emma Davies
Imperial College London

Interplanetary coronal mass ejections, ICMEs, are the main drivers of space weather at Earth which can have severe effects on systems both in space and on the ground. ICMEs with a strong southward magnetic component are the most geo-effective, thus the strength and orientation of the magnetic field of an ICME is important in forecasting space weather severity. Understanding their evolution as they propagate through the heliosphere is therefore essential.

We present analysis of the sheath and flux rope of a halo ICME registered in situ by Juno during its cruise phase on 25th October 2011 that is of particular interest, firstly, due to its large maximum magnitude field strength which caused a strong geomagnetic storm at Earth and, secondly, due to partially merging with a slower preceding halo ICME. The spacecraft is close to radial alignment with near Earth spacecraft at L1 and the Moon, however, we find that the slight longitude separation causes clear differences in the signatures observed by the Juno spacecraft in comparison to the near Earth spacecraft. Shock drivers such as ICMEs have been found to extend up to approximately 100˚ in longitude, therefore these observations illustrate the need for more longitudinal separation studies of ICMEs. This case study demonstrates the analysis techniques that could similarly be applied to observations at L5, and potentially at L1 and L5 simultaneously, to further understanding of ICME evolution throughout the heliosphere.

SAMNet - Solar Activity Monitor Network - A ground-based network to support space weather prediction

R. Erdelyi and the SAMNet Team
University of Sheffield

The interaction of solar activity with the Earth's upper atmosphere occurs through a complex series of events often referred to as Space Weather (SW). From the constant streams of particles in the form of solar wind to more energetic solar flares (M and X-class) and fast Coronal Mass Ejections

(CMEs), all stemming from solar activity, various solar events can have a major impact on life and on our modern high-tech based infrastructure both in space and on the ground.

Carrington [1859] reported a huge solar eruption that caused a strong geomagnetic storm only 17 hours and 40 minutes later. Auroras were sighted down to as low as 20 degrees geomagnetic latitudes (e.g. even in Cuba or Mexico), and electric surges occurred from ground-induced currents in telegraph wires, both in Europe and the USA. Would such a flare event occur these days, it may set back our civilisation years, if not a decade, by the damaged it may cause to our chip-driven world.

Today, one of the main questions of solar plasma-astrophysics research is to predict these potentially hazardous solar eruptions, and, to understand clearly the causes and the underlying dynamics of SW phenomena. The ultimate goal of our Solar Activity Network (SAMNet) project is to develop a reliable forecasting facility and deliver an accurate flare and CME prediction to protect mankind with its modern and sophisticated technology-base that might be at considerable risks from radiation and high-speed charged particles blowing often abruptly off the Sun. The question is not anymore "whether", but "when" a devastating flare/CME event may happen. Humanity must be ready to protect itself.

SAMNet is a UK-led international network of planned individual Solar Activity Magnetic Monitor (SAMM) stations. SAMNet, operated by HSPF (http://hspf.eu), at its full capacity will continuously monitor the Sun's magnetic field. The facility will provide routine and continuous supply of magnetic field information of solar active regions at various atmospheric heights with a resolution similar to SDO/HMI. With our key partners, a proof-of-concept robotic SAMM telescope has already been designed, built and commissioned with 2 OTAs (using K I and Na I D Magneto-Optical Filters (MOFs)). However, if we wish to improve forecasting capabilities on timescales of days (that is desired by industry), we need additional routinely taken chromospheric magnetic field data. A SAMM station, at its full capacity by adding 2 more MOF lines (Ca I and He I) for the measurement of chromospheric magnetic fields will provide exactly this purpose, enabling the needed precision and accuracy of predicting the onset of flares and CMEs up to a day in advance.

We will discuss the underlying science, called the WG_M-method, that is used to make daily predictions, and, will outline the key elements of the network. We will also address the advantages that a ground-based system has and how it is complementary to the proposed L1/L5 mission. In tandem, the two systems will make indeed the desired advances in operational space weather research.

Timescales of Birkeland currents driven by the IMF

John C. Coxon[1], Robert M. Shore[2], Mervyn P. Freeman[2], Robert C. Fear[1], Stephen D. Browett[1], Andrew W. Smith[1], Daniel K. Whiter[1], Brian J. Anderson[3]
1. Department of Physics and Astronomy, University of Southampton, Southampton, UK
2. British Antarctic Survey, Cambridge, UK
3. Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA

Effective forecasting of space weather conditions allows us to better predict geomagnetic effects on Earth. However, a key part of this is knowledge of the timescales on which solar wind-magnetosphere-ionosphere coupling operates. To this end, we obtain current densities from AMPERE and IMF By and Bz from OMNI for March 2010. For each AMPERE spatial co-ordinate, we cross-correlate current density with By and Bz, finding the maximum correlation for lags up to 360 minutes. The patterns of maximum correlation contain large-scale structures that have similar morphologies to the average current density separated by clock angle.

This novel approach enables us to see statistically the timescales on which information is electrodynamically communicated to the ionosphere after magnetic field lines reconnect at the magnetopause and in the magnetotail. Application of this technique, especially in future work focusing on timescales in case studies and specific event types, will greatly inform operational space weather capabilities.

POSTERS

SULIS: Solar cUbesats for Linked Imaging Spectropolarimetry

Eamon Scullion1, Huw Morgan2, Haosheng Lin3, Jackie Davies4, Richard Harrison4

1. Northumbria University, UK
2. Aberystwyth University, UK
3. IfA, University of Hawaii, USA
4. UKRI STFC- RAL Space, UK

Determining the 3D magnetic field of the solar corona is key to answering fundamental questions about the true nature of solar atmospheric heating and solar eruptive events driving space weather at Earth. SULIS will be a flagship UK-led space science mission, which will lead a step-change in our understanding of the key physics of the Sun-Earth environment, through innovative UK-built CubeSat (small-satellite) technology with industrial partnership. SULIS is now listed as 1 or 5 high priority, large-scale, fundable, solar system projects by STFC Science and Executive Board. SULIS consists of 3 pairs of formation flying coronagraphs, with one pair in a high Earth polar orbit, whilst the other two pairs enter 1 AU STEREO-like Earth orbits ahead of and behind Earth over a 5-year mission lifetime. The sunward CubeSat in each pair uniquely acts as an external occulter of the anti-sunward CubeSat and also houses a massively multiplexed coronal spectropolarimeter and magnetometer (USA-built) for on-disk and off-limb spectropolarimetric magnetic field inversion. The anti-sunward CubeSat houses a broadband hyperspectral imager (UK-built) for simultaneous coronagraphic imaging out to 5 solar radii. SULIS will answer important questions about the 3D properties magnetic field of the solar corona, at remarkably high cadence (~1-min), in order to determine the potential geoeffectiveness of Coronal Mass Ejections (CME's) at the earliest opportunity, as well as, tracking of CME's to determine their 3D kinematics. SULIS will compliment operational space weather missions, through exploring the science underpinning space weather sources, in order to establish better forecasting systems in future.

Space weather monitor at the L5 point: a case study of an interplanetary propagation of a CME observed with STEREO B

M. J. West, L. Rodriguez, C. Scolini and M. Mierla

An important location for future space weather monitoring is the L5 Lagrange point of the Sun-Earth system. We test the performance of such a space weather monitor using STEREO-B observations of an Earth-directed coronal mass ejection (CME) first detected on October 17, 2009. The CME, seen as a partial halo by the SOHO/LASCO coronagraph located at L1, reached the Earth on October 21 and produced active geomagnetic conditions (Kp=4). During the event, the STEREO-B spacecraft was located close to the L5 Lagrangian point of the Sun-Earth system and the CME could be continuously tracked in the fields of view of its remote-sensing instruments (EUVI, COR1, COR2, HI1, and HI2). By using the L5 data, an improved and continuously updated estimation of the CME arrival time can be provided. In this presentation the advantages of having a space weather monitor at the L5 point for tracking interplanetary propagation of CMEs are demonstrated in a direct case study.

Mapping low corona flow trends via time dependent AIA image processing
Gabriel Muro, Huw Morgan (Aberystwyth University)

Applying the Time-Normalized-Optical-Flow (TNOF) image processing technique to AIA Extreme Ultraviolet (177-305 nm) data reveals fine-scale and faint plasma motion that are tracked through optical flow methods, giving 2-D flow maps. The flows detected thus far appears to be oriented in the low corona [1,2], but the Lucas-Kanade method has known weaknesses near the solar limb, due to small separation in observational position, and varies in quality across AIA cameras. To reliably refine the method, synthetic image data is developed with a well defined velocity field and will serve as the testing platform to separate systematic biases from true flows. Once fully vetted, the strength of the project lies in understanding the faint moving disturbances that propagate and persist during the "quiet sun" period that is the standard solar condition. The method may be adapted to include elevation flow trends in/out of the low corona should tandem spacecraft be flown at L1 & L5, allowing 3-D maps of flows.

Simultaneous Rotational Analysis of Complex Multi-Spot Sunspot Groups
Richard Grimes
University of Aberystwyth

Sunspots and sunspot groups exhibit observable changes in configuration and/or internal structure during large-scale flaring events that are of interest to space weather studies. Thus, analysing sunspots and their surrounding environments helps us to understand the physics of the solar magnetic field. A new technique allows simultaneous analysis of multiple sunspot umbrae at different thresholds of plasma temperature, giving new insight into the group behaviour of these spots in the context of their interior structure. This technique is applied to a complex sunspot group that is linked to flaring activity, observed by HMI/SDO in September 2014 (NOAA 12158), and shown by Bi et al (2016) to exhibit a partial reversal in rotation during the flare. The ability for this technique to be applied to a full-disk image in near real-time has substantial benefits for use on a spacecraft obtaining continuum intensity images at L5, to support observations made by HMI/SDO.

References:
[1] Morgan, H., Druckmüller, M. 2014, Solar Physics, Vol. 289.
[2] Morgan, H., Hutton, J. 2018, Astrophysical Journal, Vol. 853.

A study of fan-shaped jets within a flaring Active Region using IRIS
Llyr Humphries
University of Aberystwyth

IRIS is a relatively low-cost, small-explorer-class NASA observatory composed of an UV telescope with an eight-inch primary mirror, together with an imaging spectrograph. IRIS's primary objective is to observe the Photosphere (PS), Chromosphere (CS) and Transition Region (TR) from a polar, Sun-synchronous orbit. Preliminary results are presented of several fan-shaped jets within a flaring Active Region. These jets exhibit interesting dynamics. Analyses have been conducted across several channels, allowing the determination of apparent speeds. This study seeks to determine if a connection exists between these jets and foot-point brightenings and/or flaring events. Determining a correlation (if any) between these small scale-events and the corona will help understand coronal heating and dynamics and, in turn, willfurther our understanding of the Sun-Earth relationship. Utilization of L4/L5 orbits for imaging and spectroscopic instruments would greatly enhance our understanding of the solar atmosphere.

A consideration of the multi-viewpoint and single-viewpoint exploitation of heliospheric imaging in light of over a decade of operation of the STEREO/HI instruments

R.A. Harrison and J.A. Davies
RAL Space

After more than a decade of successful operation of the flagship Heliospheric Imagers (HI) on-board NASA’s twin-spacecraft STEREO mission, we are in a unique position to assess the large volume of research that exploits the data therefrom. In particular, we review selected publications that characterise the 3D kinematic properties of coronal mass ejections (CME), as they propagate to 1 AU and beyond; such information is vital for the provision of accurate CME arrival predictions for space weather usage. We consider the benefits of heliospheric imaging from two vantage points over such imaging from a single view point. Given the expectation of future operational heliospheric imaging from only a single vantage point, such an assessment is timely