Abstracts

D. Bezrukovs (1), B. Ryabovs (1), and J. Kallunki (2).
Microwave Observations of "Coronal Partings" and Coronal Low Brightness Temperature Regions.
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Abstract: "Coronal partings" (CP) are specific coronal hole-like structures characterized by the depressed coronal EUV emission and the open magnetic field. The interest to CPs as to one of probable sources of the slow solar wind appeared some years ago. An association of some part of low brightness temperature regions (LTR) observed in microwaves and long waves with areas of the coronal EUV emission depression and open magnetic field lines were shown earlier also.
The analysis of low contrast microwave spectral polarimetric observations performed by Ventspils International Radio Astronomy Center (VIRAC) RT-32 radio telescope, Metsahovi Radio Observatory (MRO) and Nobeyama Radio Heliograph (NoRH) showed the close association of LTR depressed microwave emissions in the chromosphere and lower corona with CPs on the periphery of two active regions. Obviously LTRs are indicating the reduced plasma density above CPs along the open magnetic field line. The analysis of long wave LTR from the high corona needs to prove the assumption about the coronal plasma flow to the outer space crossing all layers of the corona. Additional LOFAR solar observations at very long waves have a sufficient spatial resolution to understand the full structure of open magnetic field lines in the all solar corona.
The presentation discusses possibilities and eventual results of a joint analysis of magnetograms, EUV, microwave and long wave solar observations of LTRs in order to clarify the open magnetic field structure of CPs and conditions of a charged particle acceleration in it.

M.M. Bisi (1), R.A. Fallows (2), B.V. Jackson (3), J.A. Gonzalez-Esparza (4), I. Chashey (5), M. Tokumaru (6), P.K. Manoharan (7), H-.S. Yu (3), E. Aguilar-Rodriguez (4), O. Tyul'bashev (5) S.A. Chang (4), J. Morgan (8), J.C. Mejia-Ambriz (4), K. Fujiki (6), V. Shishov (5), D. Barnes (1), and D.F. Webb (9).

The Worldwide Interplanetary Scintillation (IPS) Stations (WIPSS) Network and Initial October 2016 Space-Weather Campaign Results.

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Abstract: Interplanetary Scintillation (IPS) allows for the determination of velocity and a proxy for plasma density to be made throughout the corona and inner heliosphere. Where sufficient observations are undertaken, the results can be used as input to the University of California, San Diego (UCSD) three-dimensional (3-D) time-dependent tomography suite to allow for the full 3-D reconstruction of both velocity and density throughout the inner heliosphere. In addition, source-surface magnetic fields can also be propagated out to the Earth (and elsewhere in the inner heliosphere) as well as the incorporation of *in-situ* data into the 3-D reconstructions. By combining IPS results from multiple observing locations around the globe, we can increase both the temporal and spatial coverage across the whole of the inner heliosphere. A WIPSS website is currently under development. The WIPSS Network is bringing together the worldwide real-time/near-real-time capable IPS observatories, as well as those used on a more-campaign-only basis, with well-developed and tested analyses techniques being unified across the majority of the IPS-capable systems. During October 2016, a unique opportunity arose whereby the European-based Low Frequency Array (LOFAR) radio telescope was used to make nearly four weeks of continuous observations of IPS as a heliospheric space-weather test campaign. This was expanded into a global effort to include observations of IPS from the Murchison Widefield Array (MWA) in Western Australia, as well as many more standard analyses from various IPS-dedicated WIPSS Network systems. IPS data from LOFAR, ISEE, the MEXican Array Radio Telescope (MEXART), and where possible other WIPSS Network systems (such as LPI-BSA and Ooty), will be used in this study where we present some initial findings for these data sets and their combination. We also undertake an initial demonstration analysis of some of these WIPSS data incorporated into the UCSD tomography, and highlight the prospects of the WIPSS Network going forward.

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Investigation of Heliospheric Faraday Rotation Due to a Coronal Mass Ejection (CME) Using the Low Frequency Array (LOFAR) and Space-Based Imaging Techniques.
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(9) University of New Mexico, NM, USA,
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(12) ISEE, Nagoya University, Japan,
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Abstract: Observations of Faraday rotation (FR) can be used to attempt to determine average magnetic-field orientations in the inner heliosphere. Such a technique has already been well demonstrated through the corona, ionosphere, and also the interstellar medium. Measurements of the polarisation of astronomical (or spacecraft in superior conjunction) radio sources (beacons/radio frequency carriers) through the inner corona of the Sun to obtain the FR have been demonstrated but mostly at relatively-high radio frequencies. Geomagnetic storms of the highest intensity are generally driven by coronal mass ejections (CMEs) impacting the Earth's space environment. Their intensity is driven by the speed, density, and, most-importantly, their magnetic-field orientation and magnitude of the incoming solar plasma. The most-significant magnetic-field factor is the North-South component (Bz in Geocentric Solar Magnetic - GSM - coordinates). At present, there are no reliable prediction methods available for this magnetic-field component ahead of the *in-situ* monitors around the Sun-Earth L_1 point. Here we show progress on obtaining our results of true heliospheric FR using the Low Frequency Array (LOFAR) below 200 MHz to investigate the passage of a CME across the line of sight. LOFAR is a next-generation low-frequency radio interferometer, and a pathfinder to the Square Kilometre Array (SKA) – LOW telescope. We demonstrate our latest heliospheric FR results through the analysis of observations of pulsar J1022+1001, which commenced on 13 August 2014 at 13:00UT and spanned over 150 minutes in duration. We also show detailed comparisons to the FR results via additional context information and various modelling techniques to understand/untangle the structure of the inner heliosphere being detected. This observation could indeed pave the way to an experiment which might be implemented for space-weather purposes that will eventually lead to a near-global method for determining the magnetic field throughout the inner heliosphere.

Oyuki Chang (1), Mario M. Bisi(2), Américo González-Esparza(3), Richard Fallows(4), and Ernesto Aguilar-Rodríguez(3).
Interplanetary Scintillation (IPS) Single-Station Analysis (SSA) multi-station spectra: comparison with Cross-Correlation Function (CCF) analysis results.
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Abstract: Interplanetary Scintillation (IPS) occurs from the scattering of radio waves coming from compact radio sources that cross electron density fluctuations in the interplanetary medium. By analyzing these fluctuations in the measurements of flux intensity of galactic radio sources in a radio telescope, it is possible to infer some properties of structures in the solar wind. Studies based on observations of IPS have provided valuable information on the physics of the internal heliosphere for over 50 years. There are two techniques that provide IPS results: 1) Single-Station Analysis (SSA), where a theoretical model is fitted to the observed spectrum; and 2) Cross-Correlation Function (CCF), where two antennas separated by a few hundred kilometers simultaneously and independently observe the same radio source. In order to combine and complement solar wind speed observations , it is important to validate the results of these two IPS techniques. In this work we analyse events from previously studied observations from MERLIN (Multi-Element Radio-Linked Interferometer Network) using the CCF methodology. The SSA model fit is applied to these observations and compared with the previous results to validate the two techniques. The objective is to know the behavior of the parameters in cases studied by CCF that can be implemented in the SSA model. This work studies the capability of SSA model fit to describe complex events in the interplanetary environment and seeks to improve the adjustment of parameters from an individual spectrum to the theoretical model. The validation of these two methodologies is important to be able to combine data in real time from different radio telescopes that conform the initiative to create the Worldwide Interplanetary Scintillation Stations (WIPSS) Network to monitor solar wind structures in real time using data from IPS.

Linjie Chen, Yihua Yan, Wei Wang, Fei Liu, Lihong Geng, and Zhijun Chen.
Receiver Design Considerations for a new Interplanetary Scintillation (IPS) telescope.
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Abstract: A new Interplanetary Scintillation (IPS) radio telescope has been presented in the Chinese Meridian II project, this new IPS telescope includes one main station and two sub-stations, which locate more than 60 km away from each other. In the main station three parabolic cylinder radio antennas 140m x 30m in size will be used to receive the radio emissions from the sky, and in the two sub-stations, two 15m parabolic radio antennas will be employed to receive the signals separately. All the signals from the three stations can be correlated to calculate more detailed and accurate parameters of the solar wind. Besides, this IPS radio telescope may also be used for some other scientific observations, such as dark energy, pulsar, and VLBI, etc. In this paper, we will discuss the design considerations of this new IPS radio telescope including hardware design and signal processing chain.

M.F. Corchado Albelo (1), S.E. Gibson (2), K. Dalmasse (2), D. Nychka (2), and H. Bain (3).

NEW CORONAL MAGNETIC FIELD ENERGY DIAGNOSTIC TO ENHANCE SPACE WEATHER PREDICTION.

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Abstract: Solar flares and coronal mass ejections (CMEs) are two major drivers of space weather that pose a threat to space-bound and terrestrial technology that our society relies on daily. These events are driven by the rapid evolution of magnetic fields of the solar atmosphere which are known to be “non-potential”, meaning that there are significant currents associated with them . Such non-potential coronal magnetic fields store the energy excess suddenly released during solar flares and CMEs. They are believed to originate from two main mechanisms: (1) the emergence of non-potential magnetic fields from the solar interior into the solar atmosphere, and (2) the stressing of the coronal magnetic field by tangential flows along the lower boundary of the solar atmosphere. CME prediction diagnostics to date have focused on key features of the lower magnetic boundary and loops in solar active regions. In this study, we investigated the relationships between the non-potentiality of the coronal magnetic field and its polarimetric signatures with the goal of developing a new proxy for predicting solar flares and CMEs based on coronal polarimetric observations. For that purpose, we used numerical models of non-potential solar coronal magnetic fields and simulated their polarimetric signatures in the infrared 1074.7 nm iron (Fe) spectral line. The simulated observations consisted of linearly and circularly polarized light intensities. We examined the key topological features of non-potentiality found in these simulated observations, and the sensitivity of telescopes like NCAR’s Coronal Multi-channel Polarimeter (CoMP) to these features. We developed a new diagnostic of non-potentiality from polarimetric observations that correlates with free magnetic energy.

B. Dabrowski, A. Fron, K. Kotulak, A. Krankowski, L. Blaszkiewicz, M. Hajduk, and Sidorowicz T.
Baldy LOFAR station space weather monitoring.
Space Radio-Diagnostics Research Centre, University of Warmia and Mazury in Olsztyn, POLAND.

Abstract: Polish LOFAR station in Bałdy since its launch in 2016 takes part in solar and space weather observations. We present first solar observations performed in local mode in 2016 and 2017. In addition we show in general space weather-conected activities – University of Warmia and Mazury (UWM) runs muli-instrumental (ionosonde, scintillation GNSS receiver) ionospheric monitoring, which makes an opportunity of simultaneous observing Sun and responses in space weather events. Hereafter UWM also provides GNSS-based high resolution ionospheric total electron content maps, dedicated for the ILT purposes, which are to replace the IGS global ionospheric products.

J.A. Davies (1) and the Lagrange Remote-Sensing Consortium.
The remote-sensing package for ESA's operational Lagrange operational.
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Abstract: The space weather element of ESA's Space Situational Awareness (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 an additional so-called Lagrange (LGR) element. Under the auspices of LGR, a number of Phase A/B1 studies of an operational space weather mission to the L5 point have already been initiated. These studies cover (1) the overall system, (2) the remote-sensing payload, and (3) the in-situ payload. Having provided a general overview of the LGR programme, we will review the proposed requirements of those instruments that are to be considered as part of the remote-sensing instrument phase A/B1 study - namely a magnetograph, an EUV imager, a coronagraph and a heliospheric imager. We will focus, in particular, on the proposed performance specifications of the latter two instruments, the coronagraph and heliospheric imager, which are to be based on the SCOPE instrument (currently under Phase A/B1 study) and STEREO/HI, respectively.

C.E. DeForest (1), S.E. Gibson (2), R.C. Colaninno (3), G.T. Laurent(1), C.A. de Koning (4), and the PUNCH team.

Polarimeter to UNify the Corona and Heliosphere (PUNCH): Revealing how our star's atmosphere becomes the solar wind.

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Abstract: The Polarimeter to UNify the Corona and Heliosphere is a NASA Small Explorer mission undergoing a funded concept study (Phase A). PUNCH will yield the first truly 'big picture' perspective on how the Sun's atmosphere becomes the solar wind, by imaging the corona and heliosphere from under 1.5 degree to over 40 degrees elongation with a single integrated field of view and 3-D capability via polarimetric imaging.
PUNCH is targeted specifically at cross-scale physical processes – from microscale turbulence to global-scale shock and CME evolution – that unify the corona and heliosphere. It will reveal day-to-day global evolution of the solar wind in the outer corona, identify the causes of turbulence in the slow solar wind, and map the unexplored Alfvén surface that marks the outer frontier of the corona. Further, PUNCH will reveal heliospheric evolution of CME structure in 3-D, probe the formation processes of corotating interaction regions, and study the relationship between shock morphology and SEP productivity. PUNCH impacts a broad swath of heliophysics, from understanding of the corona and solar wind as an integrated system to the science of space weather and Bz prediction. It has strong synergies with current missions SDO, SoLO, and PSP, and planned missions such as the various L4/L5 probes.

R.A. Fallows (1), M.M. Bisi (2), Shaifullah (1) G., C. Tiburzi (3), and G. Janssen (1).
LOFAR Observations of the Full Passage of a CME.
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Abstract: Interplanetary scintillation (IPS) is the twinking in the radio signal received from compact radio sources due to density variations in the solar wind. It enables the determination of solar wind speed and estimates of solar wind density throughout the inner heliosphere. Several observations using the Low Frequency Array (LOFAR - a radio telescope centred on the Netherlands with stations across Europe) have been undertaken using this technique to observe the passage of CMEs across various points in interplanetary space. In particular, a set of long-duration observations taken over two days sought to observe the full passage, from nose to prominence material, of a CME which launched from the Sun on 28th April 2015. Our current analyses suggest that the full passage was indeed observed, with the CME taking approximately 12 hours to fully pass over the line of sight in an observation lasting 15 hours. This represents one of very-few occasions in which this has been achieved in observations of IPS. Measurement of the strength and direction of the magnetic field within CMEs as they pass through interplanetary space remains something of a “holy grail” for space-weather forecasting. One of the only methods by which this could be achieved is via the observation of heliospheric Faraday rotation (FR) in the polarised signal from either a polarised radio source or a Galactic polarised background. This is a challenging measurement which is only remotely possible using a LOFAR-type instrument. An observation of a pulsar was also taken in association with this CME to attempt measurement of the FR due to its passage. Here, we will present the latest results from these observations and some context of the CME event observed.

R.A. Fallows (1), Mevius (1) M., B. Forete (2), S. van der Tol (1), and M.M. Bisi (3).
New Insights into the Structure of the Mid-Latitude Ionosphere Using LOFAR.
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(3) RAL Space, Science & Technology Facilities Council - Rutherford Appleton Laboratory, Harwell Campus, UK.

Abstract: The Low Frequency Array (LOFAR) is a radio-astronomy array consisting of a dense core of 24 stations within an area of diameter 4km, 14 stations spread further afield across the North-East of The Netherlands, and a further thirteen stations internationally (six across Germany, three in northern Poland, and one each in France, Ireland, Sweden, and the UK). Each station is capable of observing over a wide bandwidth across the frequency range 10-240 MHz, at high time and frequency resolutions. When the stations are combined to image the radio sky using interferometry, the ionosphere can pose a significant challenge in the calibration of signal phase differences between each station. However, a side product of the calibration process is valuable information on ionospheric structures ranging in scale from tens of metres to 100km. Using only the LOFAR core stations and measuring the position shifts of many radio astronomical sources in a portion of the sky, it is possible to directly image moving ionospheric structures with a time resolution of one minute. Furthermore, using single stations in a high-time resolution mode enables ionospheric scintillation to be measured. Observations of strong natural radio sources such as Cassiopeia A and Cygnus A taken using LOFAR show almost continual ionospheric scintillation irrespective of the ionospheric space-weather conditions. Dynamic spectra of these observations show scintillation progressing through the weak- and strong-scattering regimes and sometimes also showing the effects of refraction due to large-scale structure in the ionosphere. For single observing frequencies, the normalised intensities received by each station can be plotted as images where each intensity pixel corresponds to the spatial location of the station. This results in a series of images where the scintillation intensity can be seen 'flowing' across the stations in movies created from them. Such movies demonstrate how the scintillation appears to flow across the compact core area of LOFAR in waves at highly-variable speeds, and the small-scale structure which exists well within single pixels of even high-resolution GNSS TEC maps. These novel data will be used to support and test ionospheric and scintillation modelling over a wide range of scales, and a project is currently underway to monitor TEC gradient variations over Europe, verifying GNSS IONEX data, and ulitmately, will be used to implement near-real-time imaging of ionospheric structures and TIDs.

B. Forte.

Ionospheric irregularities during adverse space weather conditions: challenges and novel approaches.

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Abstract: Space Weather causes perturbations of the geomagnetic field and the ionosphere. In turn these perturbations (i.e. geomagnetic and ionospheric storms) affect the operation of space borne and ground-based technological systems.

The challenge in understanding the real impact of space weather on terrestrial and aerospace infrastructure that rely on satellite radio signals, is the combination of the following outstanding problems: (a) what is the ionospheric response as a function of time and location to given solar events, (b) what is the effect of such an ionospheric response on radio propagation, and (c) what is the impact of disturbed propagation conditions on systems and applications (e.g. satellite positioning and navigation, satellite telecommunications, Earth Observation).

These aspects introduce challenges for the identification of countermeasures as well as for realistic forecasts.

Scintillation is one of the significant effects during adverse space-weather conditions. Scintillation can simultaneously affect both satellite based navigation and telecommunications on a daily basis and therefore can cause serious problems for infrastructure reliant on either, or both, technologies and related applications (e.g. autonomous navigation, civil aviation).

Preliminary results from studies intended to devise system-effective countermeasures as well as forecasts will be presented with the objective to stimulate discussions and explore synergies for future collaboration amongst participants.

Novel ionospheric measurements are becoming increasingly available, for example low-frequency radio telescopes. These have the potential to sample a part of the irregularities spectrum which is complementary to the GNSS-based measurements. The combination of GNSS and low-frequency measurements offers a unique opportunity to refine the understanding of the formation and evolution of ionospheric irregularities.

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Observation and Modeling of Coronal Magnetism.

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Abstract: Magnetic fields in the sun's outer atmosphere – the corona – control both solar wind acceleration and the dynamics of solar eruptions. We present progress to date on the Data-Optimized Coronal Field Model (DOCFM) project. The goal of this project is to develop a new methodology for assimilating coronal magnetic diagnostic data into magnetohydrodynamic (MHD) models in order to establish not only the magnetic structure of the source region of coronal mass ejections, but also the global field into which it erupts. In particular, we report on 1) new observational diagnostics using coronal linear polarization measurements that detect magnetic nulls and super-radial expansion of magnetic flux tubes; 2) the construction of observing system simulation experiment (OSSEs) for testing methodology; 3) a Radial-basis-function Optimization Approximation Method (ROAM) for obtaining orders-of-magnitude increases in speed vs a full grid search of parameter space; and 4) the application of ROAM to a parameterized flux-rope insertion model in order to diagnose the 3D coronal magnetic field from synthetic coronal polarization observations generated for an OSSE.

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National Laboratory of Space Weather.
SCIESMEX, Instituto de Geofisica, Universidad Nacional Autonoma de Mexico.

Abstract: The National Laboratory of Space Weather (LANCE in Spanish) was created in 2016. LANCE comprises the Mexican Space Weather Service (SCIESMEX in Spanish) and a network of ground based instruments with space weather applications. This network includes: the Mexican Array Radiotelescope (MEXART) to perform IPS observation of solar wind disturbances; a CALLISTO station to detect solar radio burst, a network of GPS receivers to produce TEC maps of ionospheric disturbances, and a magnetometer. At this moment we are expanding the network to include five ionosondes and five magnetometers. The data of this network is analyzed in near real time to identify space weather hazards and the effects on the Mexican territory. We report the first events detected by this network indicating the necessity of measuring and tracking space weather phenomena in Mexico. The country requires to estimate the risk and vulnerability of its key technological systems to space weather hazards.

L.M. Green (1), A. James (1), E. Palmerio (2), G. Valori (1), and E. Kilpua (2).
The magnetic field configuration of CMEs at the Sun.
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Abstract: A key component of predicting the geo-effectiveness of a CME when it reaches the Earth is the magnetic field configuration of the eruption. In particular, the strength and duration of the so-called Bz (southward) component determines the extent to which the CME magnetic field couples to that of the magnetosphere. The starting point for a prediction of the Bz component at Earth is the magnetic field configuration of the CME as it leaves the Sun. This talk will look at how observations provide vital clues of this magnetic field configuration and how modelling techniques can further be utilised.

R.A. Harrison (1), J.A. Davies (1), C. Perry (1), C. Möstl (2), A. Rouillard (3), V. Bothmer (4), L. Rodriguez (5), J. Eastwood (6), E. Kilpua (7), P. Gallagher (8), and D. Odstrcil (9).

HELCATS – Heliospheric Cataloguing, Analysis and Techniques Service: a Benchmark for Combining Multiple Remote-Sensing Data Sets and Modelling Techniques.

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(3) Paul Sabatier University, France,
(4) University of Göttingen,
(5) Royal Observatory of Belgium, Belgium,
(6) Imperial College London, UK,
(7) University of Helsinki, Finland,
(8) Trinity College Dublin, Ireland,
(9) GMU, VA, USA.

Abstract: Understanding the evolution of the solar wind is fundamental to advancing our knowledge of energy and mass transport in the solar system, rendering it crucial to space weather and its prediction. The advent of truly wide-angle heliospheric imaging has revolutionised the study of solar wind evolution, through enabling direct and continuous observation of both transient (coronal mass ejections: CMEs) and background (stream/co-rotating interaction regions: SIRs/CIRs) solar wind plasma structures as they propagate out to 1 AU and beyond. The recently-completed EU FP7 Heliospheric Cataloguing, Analysis and Technique Service (HELCATS) project capitalised on European expertise in the field of heliospheric imaging, built up over the last decade in particular through lead involvement in NASA's STEREO mission, whilst also exploiting the vast wealth of long-established European expertise in such areas as solar and coronal imaging as well as the interpretation of *in-situ* and radio diagnostic measurements of solar wind phenomena. The aims of the HELCATS project were: (1) to catalogue transient (CMEs) and background (SIRs/CIRs) solar wind structures observed in the heliosphere by the UK-led STEREO/Heliospheric Imager (STEREO/HI) instruments, including estimates of their kinematic properties based on a variety of established modelling techniques and the prototyping of other, more speculative, approaches; (2) to verify these kinematic properties, and thereby assess the validity of these modelling techniques, through comparison both with solar source observations and *in-situ* measurements at multiple points throughout the heliosphere; (3) to assess the potential for initialising advanced numerical models based on the derived kinematic properties of both the transient and background solar wind structures; and (4) to assess the complementarity of using radio observations (in particular Type II radio bursts and interplanetary scintillation) to detect and analyse structures in the heliosphere in combination with heliospheric imaging observations. We provide an overview of the space-weather science that was undertaken under the auspices of the HELCATS project.The benchmark HELCATS project demonstrates clearly the benefits of combining multiple remote-sensing data sets, with *in-situ* measurements and modelling techniques, in the study of the inner heliosphere.

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ADAPT Global Solar Magnetic Maps and Forecasting Space Weather.
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Abstract: Progress toward the forecasting of key space weather parameters, up to 7 days in advance, using SIFT (Solar Indices Forecasting Tool) with the ADAPT (Air Force Data Assimilative Photospheric flux Transport) model will be reviewed. Details regarding the SIFT forecasting method summarized here are outlined in Henney et al. 2012 and Henney et al. 2015. The new method utilizes the solar near-side magnetic field distribution estimated with the ADAPT flux transport model as input to the SIFT empirical models that predict typical input parameters to ionospheric and thermospheric models; e.g., selected bands (between 0.1 to 175 nm) of solar soft X-ray (XUV), far ultraviolet (FUV), and extreme ultraviolet (EUV) irradiance, along with observed F10.7 (solar 10.7 cm, 2.8 GHz, radio flux), the sunspot number (SSN), and the Mg II core-to-wing ratio. Input to the ADAPT model includes photospheric magnetograms from the NISP (NSO Integrated Synoptic Program) ground-based instruments, GONG and VSM. The ADAPT flux transport model evolves an ensemble of realizations, using relatively well-understood transport processes during periods for which there are no observations, and updates the ensemble using data assimilation methods that rigorously take into account model and observational uncertainties. We have updated the ADAPT model to utilize line-of-sight and vector magnetograms, along with helioseismic far-side detections, from the Helioseismic and Magnetic Imager (HMI) to create global radial field distribution maps. We also plan to incorporate data from the Polarimetric and Helioseismic Imager (PHI) on Solar Orbiter into ADAPT to provide uniquely vital full-disk vector magnetogram input from the far-side and higher latitude polar regions. ADAPT model development is supported primarily by AFRL, with additional support from NASA.

B.V. Jackson (1), A. Buffington (1), H.-S. Yu (1), P.P. Hick (1), and M.M. Bisi (2).
ASHI, An All Sky Heliospheric Imager for Viewing Thomson-Scattered Light – Recent Progress.
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Abstract: We have developed, and are now funded by NASA to ready for flight an All-Sky Heliospheric Imager (ASHI) for future missions. ASHI's principal objective is a precision photometric map of the inner heliosphere from deep space. The zodiacal-light photometers on the twin Helios spacecraft, the Solar Mass Ejection Imager (SMEI) on the Coriolis satellite, and the Heliospheric Imagers (HIs) on the Solar-TErrestrial RElations Observatory (STEREO) twin spacecraft, all point the way towards an optimum instrument for visible light Thomson-scattering observations. The system we have designed includes viewing the whole sky starting beyond a few degrees of the Sun, and covering a hemisphere or more of sky. A key photometric specification for ASHI is 0.1% differential photometry which enables the 3-D reconstruction of density starting from near the Sun and extending outward. SMEI analyses have demonstrated the success of this technique: when employed by ASHI, this will provide an order of magnitude better resolution in three dimensions over time. As a new item we include velocity in this concept, and for a heliospheric imager in deep space, the ability to provide both high-resolution comparisons of in-situ density and velocity measurements obtained at the spacecraft to solar wind structures observed remotely. In practice we find that 3-D velocity determinations allow a better-timing depiction of heliospheric structures, especially those that are not Earth directed, and we discuss the simple concept behind this as well as the instrument development progress, characteristics, and specifications to date.

B.V. Jackson (1), H.-S. Yu (1), P.P. Hick (1), A. Buffington (1), M. Tokumaru (2), J. Kim (3), and J. Yun (4).
Bz Determinations and Forecasts Using the UCSD IPS Analysis.
(1) Center for Astrophysics and Space Sciences, University of California, San Diego, United States,
(2) Institute for Space-Earth Environmental Research, Nagoya University, Nagoya, Japan,
(3) Korean Space Weather Center, National Radio Research Agency, 198-6, Gwideok-ro, Hallim-eup, Jeju-si, Jeju-do, 695-922 South Korea,
(4) Solar Environment Laboratory, 8, Nonhyeon-ro 150-gil, Gangnam-gu, Seoul, South Korea.

Abstract: Since the middle of the last decade, UCSD has incorporated magnetic field data in its ISEE IPS tomographic analysis. These data are extrapolated upward from the solar surface using the Current Sheet Source Surface (CSSS) model (Zhao & Hoeksema, 1995) to provide predictions of the interplanetary field in RTN coordinates. With the help of initial funding from the Korean Space Weather Center, and a recent AFOSR research contract, the technique used to provide magnetic fields has become ever more sophisticated. The technique now allows different types of magnetogram data (SOLIS, GONG, etc.,) to be incorporated in the extrapolations, and also allows inputs from all three field components at the model source surface. When extrapolated to Earth, these fields can be displayed in a variety of ways, including GSM fields in Bx, By, and Bz coordinates. Displayed on a daily basis, our long-used CSSS model analysis, to our surprise, showed that a significant positive correlation exists between the extrapolated GSM fields and in-situ measurements of the Bz field component. This few nano-Tesla variation of Bz maximizes in spring and fall as Russell and McPherron (1973) have shown, but even more significantly its daily variation is shown well-correlated with geomagnetic Kp and Dst indices. UCSD currently operates a website that predicts this low resolution GSM Bz field component variation several days in advance. We show examples of the predicted enhanced geomagnetic activity associated with southward dips of the Bz component.

David Jackson (1), Siegfried Gonzi (1), Mario Bisi (2), and Marion Weinzierl (3).
Heliospheric model forecasts at the Met Office and the role of interplanetary scintillation observations.
(1) Met Office, Exeter, UK,
(2) STFC Ral Space, Harwell, UK,
(3) Durham University, Durham, UK.

Abstract: The Met Office Space Weather Operations Centre (MOSWOC) has been running a 24/7 service for over 3 years and during this time the range and quality of space weather models it runs has steadily increased. This includes new models to forecast the radiation belts and the aurora and the development of an ensemble prediction system for solar wind and coronal mass ejections (CMEs). A long-term aim is the development of a coupled Sun to Earth forecast model system.
A major benefit of this coupled modelling system should be the prediction of the impact of CMEs in the Earth's atmosphere and at the Earth's surface. However, as a first step, even before this coupled system is constructed, we need to ensure that CMEs are adequately represented in heliospheric models. Here, we present results from the WSA Enlil model used at the Met Office, including a comparison between WSA Enlil and simulations where the Enlil inner boundary is instead driven by initial conditions derived from interplanetary scintillation (IPS) observations. The results indicate how important it is to develop a network of global space weather operational observations which include both IPS and space-based observations. The possible applications of such data to improved heliospheric model forecasts via both data assimilation and near-real time "pruning" of ensembles shall be discussed.

N.K. Jackson-Booth (1), P.L. Martin (1), R.A. Buckland (1), Penney (1) R.W., and J. Parker (2).
Latest developments with the Electron Density Assimilation Model (EDAM).
(1) QinetiQ, Malvern Technology Centre, St Andrew Road, Malvern, Worcestershire, UK, (2) Aberystwyth University, Aberystwyth SY23 3FL.

Abstract: Comprehensive, global and timely specifications of the earth's atmosphere (particularly refractivity profiles of the troposphere and ionosphere) are required to ensure the effective operation, planning and management of many radio frequency systems. One way of providing ionospheric refractivity information is to employ an ionospheric data assimilation system. Such systems can produce 3D images of the ionosphere using data provided by a range of measurement techniques such as GPS receivers and ionosondes.
The Electron Density Assimilative Model (EDAM) has been developed by QinetiQ to assimilate disparate ionospheric measurements (including ground and space based total electron content (TEC) measurements, height profiles from ionosondes and incoherent scatter radars and electron density data from in-situ sensors) into a background ionospheric model.EDAM exploits optimal data assimilation techniques that have been developed in the meteorological community over the past few decades. The philosophy has been to design a system that will operate on a single PC, which will continue to provide physical results with very sparse data and from which products can be derived for a range of RF systems.
This paper will discuss recent developments with EDAM, including the assimilation of Forward Oblique Ionograms and validation of the model at high latitudes.

Curt A. de Koning (1,2) and Craig DeForest (3).
Using Multi-View Polarimetry to Investigate a CME White-Light Cavity.
(1) Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO,
(2) Space Weather Prediction Center (SWPC), NOAA, Boulder, CO,
(3) Southwest Research Institute, Boulder, CO.

Abstract: On 2010 April 3, the twin NASA/STEREO spacecraft observed a coronal mass ejection (CME) in total and polarized brightness white light using the SECCHI/COR2 corornagraphs. Previous attempts to exploit the full range of multi-view white light imagery for CME reconstruction has met with limited success because of noisy imagery. Using a recently developed noise-gating process to improve the signal-to-noise ratio in COR2, we demonstrate that we can spatially isolate features within a CME. In particular, we identify and measure the properties of a white-light cavity. Since such a cavity is often associated with a CME flux rope, we suggest that combining total brightness measurements and degree of polarization imagery can be used to investigate CME flux ropes.

Giovanni Lapenta, V. Olshevsky, F. Bacchini, D. Gonzalez-Herrero, E. Boella, and M.E. Innocenti.
Modelling Space Weather from the macroscopic to the kinetic level.
KULeuven.

Abstract: We will report on our ongoing efforts on studying space weather over multiple scales. The model of space weather requires to us consider global scales, in essence the whole solar system. At the same time these large scale processes are linked to and enabled by small scale processes such as reconnection, shocks and wave-particle interaction as part of the turbulence cascade or caused by specific instabilities. How can we treat this? We report here on our strategy based on using particle in cell (PIC) methods. First, we need to clear the field from a misconception, PIC is not only kinetic. PIC methods were in fact first invented for Lagrangian models of fluids. PIC methods are used in solid mechanics to study materials of various types, from solids to granular to composites. We are in fact using a single strategy the PIC method to study all scales. The Slurm code is based on the Lagrangian formulation of the MHD equations and is developed to study the solar wind at macroscopic scales. The use of a Lagrangian formulation is especially suitable for the solar wind as the solar wind to a first approximation expands radially outward, a process that Lagrangian methods include automatically with exact precision, removing one of the biggest costs of competing Eulerian codes. The iPic3D and its successor ECsim, describe plasmas at the kinetic level. Here a new exact energy conserving semi implicit formulation allows us to select any desired range of scales. We can use ECsim to study electron scale processes or we can use it at the ion scale or we can use it at the macro scale. The width of the range is determined by the number of cells we can afford but the minimum or the maximum of the scales remove is entirely determined by the user. This is a sharp contrast to competing explicit methods that are required to always resolve electron Debye scales to ensure stability. Explicit codes have very limited application to space weather because of that. Semi-implicit instead is perfectly suited for space weather studies.
As mentioned above, semi-implicit allows to decide the scales but is still limited in the range of scales by the number of cells. We have developed a new method, called multi-level multi-domain (MLMD) to make connected and intercommunicating simulations at different scales to expand the dynamical range and cover all scales of interest.
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[3] Innocenti, M. E., Beck, A., Ponweiser, T., Markidis, S., & Lapenta, G. (2015). Introduction of temporal sub-stepping in the multi-level multi-domain semi-implicit particle-in-cell code Parsek2D-MLMD. Computer Physics Communications, 189, 47-59.

S.T. Loi (1,2,3), T. Murphy (2,3), I.H. Cairns (4), C.M. Trott (2,5), and N. Hurley-Walker (5).

Exploring the terrestrial ionosphere using next-generation radio telescopes: results from the MWA.

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(2) ARC Centre of Excellence for All-sky Astrophysics, Sydney, New South Wales, Australia,
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(4) School of Physics, University of Sydney, Sydney, New South Wales, Australia,
(5) International Centre for Radio Astronomy Research, Curtin University, Bentley, Western Australia, Australia.

Abstract: The new generation of radio astronomical telescopes, which includes the Murchison Widefield Array (MWA), Low Frequency Array (LOFAR) and upcoming Square Kilometre Array (SKA), possess many novel characteristics that distinguish them from their dish-based predecessors. Their relatively lower operating frequencies (¿1 GHz) imparts them with a much greater sensitivity to phase perturbations associated with spatial variations in the electron density along lines of sight to celestial sources of radio emission. This, combined with their wide instantaneous fields of view, the speed of electronic beamforming and the high spatial density of suitable radio sources, allows them to probe the ionosphere at unprecedented speed and spatial resolution. The regional (1-100 km) scales to which they are sensitive fills a useful niche in the study of ionospheric irregularities, compared to conventional techniques such as radar scattering and GPS, which probe much more local and global scales, respectively.
In this talk, I present results of MWA studies of ionospheric structures and dynamics occurring above the Murchison Radio-Astronomy Observatory (26.7°S geographic, 38.6°S geomagnetic) in Western Australia, also the site of the future low-frequency component of the SKA. The observed structures fall into two main classes: (i) travelling ionospheric disturbances and (ii) field-aligned irregularities. I show how the MWA can be used to measure various properties of these structures, such as their spatial scales, propagation/drift speeds and azimuths, altitudes, inclinations and growth/decay rates. Notably, all data used were originally obtained for the purposes of radio astronomy, demonstrating that ionospheric research can be a fully commensal application of these instruments alongside radio astronomical research.

C. J. Lonsdale.
Progress in Solar Imaging and Heliospheric Studies with the MWA.
MIT Haystack Observatory.

Abstract: The Murchison Widefield Array (MWA) is a powerful instrument for high precision radio imaging of the Sun and for detecting propagation effects in the heliosphere. By virtue of its outstanding aperture sampling and a 30 degree wide field of view, the MWA offers the potential of measuring both interplanetary scintillation and Faraday rotation, simultaneously across large volumes of the heliosphere. Such measurements, when conducted at modest solar elongations (i.e. during the daytime) can provide extensive information about the plasma in interplanetary CMEs, and in particular can strongly constrain Bz and its evolution as the iCME propagates.
However, fulfilling this promise will generally require unprecedented levels of imaging fidelity and dynamic range in order to determine and then subtract the overwhelmingly strong solar radio emissions, so that the relatively faint background sources of emission, both discrete and diffuse, can be studied in sufficient detail. We report major progress that has been achieved in high dynamic range solar imaging with the MWA, paving the way toward routine daytime propagation studies, and the design of future dedicated heliospheric monitoring instruments capable of enhancing space weather prediction capabilities.

J. Magdalenic (1), C. Marque (1), R. Fallows (2), G. Mann (3), C. Vocks (3), and other core members.
Fine structures of type III radio bursts observed by LOFAR.
(1) Royal Observatory of Belgium, Brussels, Belgium,
(2) ASTRON, Netherlands Institute for Radio Astronomy, Dwingeloo, Netherlands,
(3) Leibniz-Institut für Astrophysik Potsdam, Potsdam, Germany.

Abstract: On August 25, 2014, NOAA AR 2146 produced the M2.0 class flare (peaked at 15:11 UT). The flare was associated with a coronal dimming, a EUV wave, a halo CME and a radio event observed by LOFAR (the LOw-Frequency Array). The radio event consisted of a type II, type III and type IV radio emissions. In this study, we focus on LOFAR observations of the type III bursts, generally considered to be radio signatures of fast electron beams propagating along open or quasi open field lines. The group of type III bursts was, as usually, observed during the impulsive phase of the flare. At first hand, type III bursts show no peculiarity, but the high frequency/time resolution LOFAR observations reveal that only few of these type III bursts have a smooth emission profile. The majority of bursts is strongly fragmented. Some show a structuring similar to type IIIb bursts, but on a smaller frequency scale, and others show a non-organized patchy structure which gives indication on the possibly related turbulence processes. Although fine structures of type III bursts were already reported, the wealth of fine structures, and the fragmentation of the radio emission observed in this August 25 event is unprecedented. We show that these LOFAR observations bring completely new insight and pose a new challenge for the physics of the acceleration of electron beams and associated emission processes.

G. Mann and C. Vocks.

Tracking of an electron beam through the solar corona with LOFAR.

Physics of the Sun, Leibniz Institute for Astrophysics Potsdam, Potsdam, Germany.

Abstract: The Sun's activity occurs by various phenomena such as bursts of radio emission. Solar type III radio bursts are signatures of beams of energetic electrons propagating along magnetic field lines in the corona. Here we present novel interferometric LOFAR (LOw Frequency ARray) observations of a solar type III radio burst with unprecedented spectral, spatial, and temporal resolution. With LOFAR's spectroscopic and imaging capabilities the propagation of the type III radio burst can be studied. It provides evidences for the propagation of the radio source along the coronal magnetic field lines. The evolution of the type III burst shows a nonuniform movement of the radio burst source in the corona. That can be expained, that the type III radio burst is not generated by a monoenergetic electron beam, but by an ensemble of energetic electrons with a spread distribution in velocity and energy. The study was performed by a close collaboration with the LOFAR team at ASTRON and the team of LOFAR's solar key science project.

Periasamy K. Manoharan.
Space Weather Events – Ooty Interplanetary Scintillation Studies.
Radio Astronomy Centre, National Centre for Radio Astrophysics (TIFR), Udhagamandalam (Ooty), 643001, India.

Abstract: The knowledge of the radial evolution of 3-D structure and speed of a coronal mass ejection (CME) in the inner heliosphere is essential to infer its interaction with the disturbed/ambient solar wind in the course of its propagation, to accurately predict its arrival time at the near-Earth space, and to understand its space weather effects. The interplanetary scintillation (IPS) technique provides an essential tool to track CMEs and their associated disturbances in the Sun-Earth space and it has demonstrated the ability to make correct association between CMEs and their effects at the Earth's environment. In this talk, I will review the investigations of 3-D distribution of speed and density structures of CMEs in the inner heliosphere, based on IPS measurements obtained from the Ooty Radio Telescope (operated by National Centre for Radio Astrophysics, Tata Institute of Fundamental Research). Ooty measurements provide estimates of solar wind at most of heliospheric latitudes and in the distance range of $\sim$10–250 solar radii. Such estimates along a large number of lines of sight through the heliosphere can also be useful in the reconstruction of 3-D structures of quasi-stationary solar wind as well as propagating transients in the inner heliosphere. The IPS results on some specific CMEs are discussed to understand the propagation effects associated with the ambient solar wind. For example, in the current solar cycle, though weak, some large active regions produced several sets of wide, fast, geoeffective CME events (e.g., CMEs occurred during June 2015 and September 2017). Ooty solar wind density and velocity images have been extremely useful in following the propagation characteristics of these events. The results on three-dimensional evolution of size and speed of solar wind transients are reviewed on the possibility of forming a basic model to forecast the arrival/impact of solar and solar wind generated space weather effects at the Earth or else where.

J. Morgan, R. Chhetri, J-P. Macquart, and R. Ekers.
Interplanetary Scintillation Observations with a New Generation of Radio Telescopes: Progress from the MWA.
Curtin University.

Abstract: Previous IPS studies have generally relied on single concentrated collecting areas (either phased arrays or dishes). The Murchison Widefield Array (MWA) by contrast is a new-generation instrument consisting of a 128-element interferometer with an extremely wide field of view, and outstanding instantaneous imaging capability. This enables the IPS studies of 1000 sources simultaneousy, increasing the density of measurements by a factor of two or more.
In this talk I will report on progress from an ongoing IPS survey with the MWA where observations are made simultaneously at 79MHz and 150MHz. Dual frequency measurements allow solar wind velocities to be determined even with a single station. Furthermore, the different refractive indices at different wavelengths leads to a lag in the cross correlation of the two frequency bands. This allows the bulk density of the outer solar corona to be probed along multiple lines of sight. I will discuss recent results and how they might be integrated into international Space Weather Prediction efforts.

D. Odstrcil.

Propagation of Spheromaks in the Heliosphere and Prediction of Bz at Earth.

George Mason University, Fairfax, Virginia, USA and NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

Abstract: Coronal mass ejections (CMEs) are important drivers of various types of heliospheric disturbances. We have developed the WSA-ENLIL-Cone modeling system that enables routine, event-by-event, and much faster than real time simulations of CMEs as hydrodynamic structures. This system provides the global view of the coronating and transient solar wind structures and it enables predictions of the CME arrival times (ejecta and/or shock). It also provides alerts of the long-duration solar energetic particle (SEP) events and provides synthetic white-light imaging (J-maps) for eventual mid-course correction of the predictions. Magnetic spheromaks can be launched into the heliospheric computational domain in a similar manner as the hydrodynamic ejecta currently used in the operational WSA-ENLIL-Cone model. These transients are less realistic than the magnetic flux ropes; however, the existing operational tools can be used to determine their geometric and kinematic parameters and empirically estimate its magnetic parameters. With respect to the cone model, the spheromak model provides more realistic radial extent and more realistic density structure that improves predictions at Earth and comparison with remote imaging. However, spheromaks also enables to estimate strength and duration of the Bz event at Earth and this would be a crucial improvement over the existing operational model. We present numerical simulations of few selected historic CME events as demonstration and verification of this new approach to operational modeling of the heliospheric space weather.

Mariusz Pozoga, Barbara Matyjasiak, Hanna Rothkaehl, Marcin Grzesiak, Dorota Przepiórka, and Roman Wronowski.
Observations with LOFAR PL610 station in Borówiec.
Space Research Centre PAN.

Abstract: Scintillation phenomenon occurs as a result of variations in the refractive index of the medium through which waves are travelling. In particular, the Earth's ionosphere is a strongly variable medium where high density gradients occur. For this reason scintillation measurements may be successfully used to study the irregular structure of the ionosphere. On the other hand, interplanetary scintillation produces diffraction patterns on the electron density irregularities in the solar wind and may be a valuable information about its local speed.
The Polish station PL610 in Borówiec is a part of the international LOFAR ILT. The LOw Frequency ARray (LOFAR) designed for studying distant astrophysical radio sources operates in 10-270 MHz: the frequency range very suitable for studying weak scintillation regimes that prevail in mid-latitude ionosphere. LOFAR gives the opportunity of directional observations (beam forming) which allows to observe distant as well as close radio sources such as the Sun or Jupiter, but also study certain regions of the medium in between.
During the local mode periods strong radio sources like Cassiopea A and Cygnus A (LOFAR bright A-team sources) and a few bright quasars have been observed in order to measure ionospheric and interplanetary scintillations. A Few runs of measurements were made in full LOFAR bandwidth to establish a daily statistics of ionospheric scintillation index S4. The S4 index is one of the most frequently used parameters to describe ionospheric disturbances. It is computed from the raw amplitude measurements and for frequency range 138 MHz to 2.9 GHz is proportional to $\lambda^{1.5}$ (where λ is wave length). Due to the availability of very good frequency and time resolution of observations even very dynamic changes of scintillation index and, hence, ionospheric conditions can be monitored.
We present several examples of LOFAR signal analysis that contains signatures related to scattering of the radiosource signal on solar wind and ionospheric structures along with an underlying discussion giving theoretical base for analysis and concerning advantages and limitations of the method.

Pete Riley.
Predicting IMF Bz: Challenges and Successes.
Predictive Science Inc., San Diego, CA.

Abstract: The southward component of the interplanetary magnetic field plays a key role in many space weather-related phenomena. However, thus far, it has proven difficult to predict it with any degree of accuracy. In this talk I outline the difficulties in making such forecasts, and describe several promising techniques that may ultimately prove successful. In particular, I focus on predictions of magnetic fields embedded within interplanetary coronal mass ejections (ICMEs), which are the cause of most large, non-recurrent geomagnetic storms. I discuss several complementary techniques that are already producing modest, but promising results. These range from statistically-based approaches to fully-self-consistent global MHD models of CME eruption, propagation, and evolution in the solar wind. I highlight the uncertainties associated with these predictions, and, in particular, identify areas that can be refined in the future.

Pete Riley, Jon A. Linker, Cooper Downs, Tibor Torok, Viacheslav Titov, Ronald M. Caplan, Roberto Lionello, and Zoran Mikic.
*CORHEL-CG: A Tool for Simulating Coronal Mass Ejections**.
Predictive Science Inc.

Abstract: Coronal Mass Ejections (CMEs) are magnificent solar eruptions that propel plasma and magnetic fields outward from the sun. They are associated with some of the most severe space weather events, including geomagnetic storms. At the present time, operational forecasts of CMEs use the WSA-Enlil model with "cone model" CMEs to predict the arrival of possibly geoeffective CMEs at Earth. This model has no embedded magnetic fields in the CME, and therefore does not make useful predictions of southward IMF (Bz), a key driver of geomagnetic activity. There is a wealth of remote solar observations for constraining the magnetic field in CMEs both prior to and when they erupt; however, coronal CME simulations applicable to real events usually must be performed by experts and are typically very manpower intensive. The goal of our project is to develop CORHEL-CG, a tool to allow non-experts to simulate CMEs in realistic coronal magnetic fields. We describe the first version of the tool, which allows users to specify pre-eruptive configurations based on modified Titov-Demoulin (TDm) flux ropes in zero-beta MHD.

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Justyna Sokol and Maciej Bzowski.
The out of ecliptic solar wind a key to understand heliosphere.
Space Research Centre Polish Academy of Sciences (CBK PAN), Warsaw, Poland.

Abstract: The extended solar corona in the form of solar wind carves a cavity in the local interstellar medium called the heliosphere. Thinking of the heliosphere at a global scale raises questions about its shape, dimensions, structure, and boundaries. Study of the heliosphere with the use of traditional astronomy is hardly possible. Valuable information can be obtained using in-situ method, but for practical reasons synergy based on remote-sensing methods is highly needed. These latter methods include spectroscopic and photometric observations in EUV and sampling of energetic neutral atoms (ENAs) that propagate in the heliosphere. The EUV observations of the heliosphere have now been available for a few decades. And the continuous ENA sampling is available for almost the complete solar cycle. In this talk we will present a subjective review of some of the methods to study the boundaries of the heliosphere, its interaction with the local interstellar medium, as well as the influence of the inner heliosphere on the interpretation of the 1 AU measurements with a special attention paid to the importance of knowing the global structure of the solar wind. The successful studies of the ENAs, heliospheric backscatter glow, interstellar neutral gas, and pick-up ions were largely enabled by the knowledge on the solar wind variation with latitude in time. The latitudinal ordering of the solar wind and its variation in time from several years to several solar cycles is reflected in the IBEX ENA ribbon and ENA full-sky distribution, in the spectra of ENAs in the energy range 0.7-4.3 keV, and in the latitudinal dimming of the heliospheric Lyman-α glow. It also seems important for the understanding of the formation of the downwind heliosphere. These conclusions confirm the high importance of the availability of continuous observations of the solar wind at all heliolatitudes over long time intervals.

Caterina Tiburzi (1,2).
Low-frequency pulsar observations as probes of the Solar wind.
(1) Max-Planck-Institut fuer Radioastronomie, Bonn (Land Nordrhein-Westfalen, Germany),
(2) Universitaat Bielefeld, Bielefeld (Land Nordrhein-Westfalen, Germany).

Abstract: We use the six international LOFAR stations in Germany as standalone telescopes to observe more than 100 pulsars every week. To date, we have collected almost 4 years of high quality data at this unprecedented cadence. Such data set allows us to give an extraordinary characterisation of the ionised plasma along the line-of-sights toward the pulsars, both in terms of electron density and magnetic content. In this talk, I will give an overview of our unique data set and I will focus on our studies about the Solar wind.

Munetoshi Tokumaru, K. Fujiki, K. Iwai, N. Nishimura, and K. Tawara.
Global observations of the solar wind using interplanetary scintillation.
Institute for Space-Earth Environmental Research, Nagoya University, Nagoya 464-8601, Japan.

Abstract: Interplanetary scintillation (IPS) of radio sources with a small angular diameter serves as an effective tool for remote sensing of the solar wind plasma. We have performed IPS observations of the solar wind regularly since 1980s using the multi-station 327MHz IPS system of the Institute for Space-Earth Environmental Research (ISEE) of Nagoya University. The solar wind speed and the scintillation level, which is used as a proxy of the solar wind density, are determined from ISEE IPS observations. An important point of the IPS observations is that they enable reliable determination of 3D distribution of the solar wind through the tomographic analysis. Some interesting features of the solar wind have been revealed from studies based on our IPS observations which cover more than 3 solar cycles; those are solar cycle variation of global solar wind structure (including heliospheric response to weakening of the solar dynamo activity in the current cycle), close relation between the solar wind and the coronal magnetic field, propagation of IP disturbances associated with CMEs. We will present recent results obtained from our IPS studies.

C. Vocks and G. Mann.
LOFAR observations of the quiet solar corona.
Physics of the Sun, Leibniz-Institute for Astrophysics Potsdam, Potsdam, Germany.

Abstract: The solar corona is the hot, tenuous outer atmosphere of the Sun. It is highly structured due to coronal magnetic fields, but generally shows a barometric density profile along magnetic fields, for altitudes well below the sonic critical point that marks the transition towards the supersonic solar wind. If the Sun is observed at a given radio frequency, then the corona becomes opaque below the density level where that frequency corresponds to the local plasma frequency, that is a function of electron density only. LOFAR's frequency range corresponds to the middle (high band) and upper (low band) corona. Since the refractive index of a plasma approaches zero for radio waves near the local plasma frequency, refraction effects are important. A ray path through the solar corona shows total reflectance and cannot connect a source that is located near the solar limb and at such a coronal height, where the wave frequency equals the local plasma frequency, with an observer on Earth. This has important consequences on the appearance of the low-frequency radio Sun under quiet conditions. The diameter of the radio Sun increases with decreasing frequency, as expected from the relationship between electron density and plasma frequency. But it does not appear as a disk with constant brightness temperature, even for an isothermal corona. So deriving the radius of the radio Sun requires fitting of observed intensity profiles to ray-tracing simulations, based on free-free radio wave emission and absorption, as well as refraction. These simulations also depend on the plasma conditions above that radius. LOFAR's capability of simultaneously observing a broad frequency range enables the derivation of a consistent coronal density model. We'll present results for polar coronal density and temperature profiles based on LOFAR low band images.

Angelos Vourlidas.
Heliospheric Imaging from the Solar Probe and Solar Orbiter Missions.
JHUAPL.

Abstract: Pioneered by Coriolis/SMEI and established by the STEREO/SECCHI HIs, imaging of the inner heliosphere has brea thed fresh air in Heliophysics. The regular availability of synoptic, spatially resolved images of transients and quiesc ent solar wind structures as the propagate from the inner corona to 1 AU and beyond is driving major advances in our und erstanding of the inner heliosphere and is bringing the space physics and solar communities together.
The future is going to get even brighter thanks to two unprecedented space missions, Parker Solar Probe (PSP) and Solar Orbiter (SO), to be launched in 2018 and 2019, respectively. These missions are designed to attack the solar wind proble m head-on with comprehensive suites of remote sensing and in-situ instruments.
In this talk, I focus on the capabilities and science plans of the SPP and SO heliospheric imagers and discuss the exciting synergies with other space- and ground-based assets for basic and space weather research.

Wei Wang, Yihua Yan, Sha Li, Cang Su, and Chen Linjie.
A Prestudy of Cylinder antenna for Chinese IPS telescope.
National Astronomical Observatories, Chinese Academy of Sciences.

Abstract: Ground-based observation for Interplanetary Scintillation (IPS) of compact radio sources at metric waveband is a useful method to investigate solar wind. Under the support of Meridian II project, a new IPS telescope with 3 stations and dual frequencies was proposed in China, its construction will begin in the next few years. In this talk, some techniques on cylinder antenna will be discussed, including type of feed, antenna efficiency, pointing instability and others. We expect it will be a high performance antenna with capability of IPS observation.

David F. Webb.
Remote Sensing of the Heliospheric Propagation of Coronal Mass Ejections.
ISR, Boston College, Chestnut Hill, MA USA.

Abstract: Coronal mass ejections (CMEs) are a key link between solar activity and large interplanetary disturbances. They drive significant space weather effects in the heliosphere including shock waves and SEPs, and at Earth are associated with radiation effects and geomagnetic storms. Remote-sensing techniques have been used to track CMEs through the inner heliosphere, but in past decades were limited to radio IPS observations. Since 2003 (SMEI) and 2007 (STEREO HIs), we have been able to track CMEs in white light far away from the Sun with wide-field heliospheric imagers. Many spacecraft or Earth-directed CMEs have now been tracked and their signatures detected in-situ at L1/Earth by ACE or Wind and/or by one or both STEREO spacecraft. Based on my involvement with the STEREO Space Weather Group and the International Study of Earth-affecting Solar Transients (ISEST) Working Group on Campaign Events, I will highlight some aspects of the propagation of CMEs through the heliosphere and how our understanding of transients can be improved by combining remote-sensing techniques including the proposed WIPSS network.

D.R. Williams (1), A. De Groof(1), A. Walsh(1), J. Lefort(1), P. Osuna(1), D. Mueller(2), and Y. Zouganelis (1).
The Solar Orbiter Mission: Sensing the Sun Up-Close.
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Abstract: In the next couple of years, ESA's Solar Orbiter mission will carry a ten-instrument payload far beyond the confines of the Earth. The mission will address its objectives by making highly detailed observations of the solar wind as it swoops elliptically around the Sun. In the parts of its orbit closest to the Sun, it will examine the constantly changing face, atmosphere and interior of the star that produces this heliosphere. However, the challenge of linking the behaviour of the star to the plasma and magnetic field that it throws off will be up to the worldwide heliophysics community to answer!
In this presentation, we discuss the challenges and rare opportunities afforded by this mission to our nearest star, and present key operational concepts which will enable it to deliver unique results.

Yihua Yan (1,2), Wei Wang(1), Linjie Chen (1), Fei Liu (1), Lihong Geng (1), and Zhijun Chen (1).
A Design for IPS Telescope in China.
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Abstract: Interplanetary Scintillation (IPS) of compact radio sources at meter to centimeter wavelengths is a useful ground-based method to investigate solar wind structure and parameters. The available methods for IPS observation include single station with large telescope/array, or multiple stations with intermediate size of antennas. To combine advantages of the single station and multi-stations, we propose a new design for the IPS telescope with large collecting area at one main station and small antennas at other sub-stations.

A.R. Yeates and C. Lowder.
Friction, flux ropes and field line helicity: modelling CME initiation.
Department of Mathematical Sciences, Durham University, UK.

Abstract: Coronal mass ejections (CMEs) are a major source of space weather coming from our Sun. It is now believed that many (if not all) CMEs originate in the eruption of a twisted magnetic flux rope from the low corona. However, the majority of CME models consider only a single localized region, where they impose the initiation of the eruption (in one way or another). They do not address the wider questions of where on the Sun, or when, such eruptions will occur. Our work represents an attempt to probe these wider questions, using a simplified "magneto-frictional" model for the global coronal dynamics. I will show recent results where we use a new tool - the so-called "field line helicity" - to identify flux ropes in the simulated corona. This allows us to measure their flux and helicity content before they erupt, generating statistics over a full solar cycle for the model "CME output". This abstract is relevant to the "Bz" theme and was invited.

P. Zucca (1), D. Morosan (2), P.T. Gallagher (2), A. Rouillard (3), R.A. Fallows (1), J. Magdalenic (4), C. Vocks (5), C. Marqué (5), K-L. Klein (6), M.M. Bisi (7), and Gottfried Mann (5).

Study of the signature of a coronal shock with LOFAR and multi-viewpoint observations, space weather implications.

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Abstract: Type II radio bursts are evidence of shocks in the solar atmosphere emitting radio waves ranging from metric to kilometric lengths. These shocks may be associated with coronal mass ejections (CMEs) reaching super-Alfvenic speeds. These radio signature are key to understand the relationship between CMEs and shock waves and to define the input for space weather modelling and to forecast the arrival time of shocks and CMEs on Earth.

Radio imaging of the decameter wavelengths is now possible with the Low Frequency Array (LOFAR), opening a new radio window to study coronal radio shocks leaving the inner solar corona and entering the interplanetary medium and understand their association with CMEs. Here, we study a coronal shock associated with a CME and type II radio burst to determine the location where the shock is triggered in relation to the propagating CME, the ambient medium Alfvén speed and the orientation of the coronal magnetic field. The type II shock imaging and spectra were obtained using 91 simultaneous tied-array beams of LOFAR while the CME was observed and triangulated using multi-viewpoint observations including the Solar and Heliospheric Observatory (SOHO) and the Solar Terrestrial Relations Observatory (STEREO).

Using the tied array beam observing mode of LOFAR we were able to locate the type II radio shock position between 45 and 75 MHz and relate it to the expanding flank of a CME leaving the inner corona. With the key help of the multi-viewpoint observations, the radio emission associated with the type II burst was found to be located at the flank of the CME in a region where the mach number is between 1.5 to 2.0 and the shock geometry is quasi-perpendicular. These parameters will contribute to the modelling of the propagation of shocks and CMEs for space weatherer purposes.