|  |
| --- |
| WORK PACKAGE 7 (WP7):  ASSESSING THE COMPLEMENTARY NATURE OF RADIO MEASUREMENTS OF SOLAR WIND TRANSIENTS |
| WP7 ACTIVITY TYPE: RTD |
| WP7 DURATION: MONTHS 10 – 36 |
| WP7 LEAD BENEFITIARY: IMPERIAL (6) |
| WP7 LEADER: Dr Jonathan Eastwood |
| WP7 CONTRUBUTORS: STFC (1); ROB (5) |
| WP7 OVERVIEW: As has been previously described, the main goal of HELCATS work package 7 is to assess the potential for combining white-light imaging of the inner heliosphere with both ground- and space-based radio data, in particular Interplanetary Scintillation (IPS) and Type II radio bursts. WP7 is divided into two activities.  Task 7.1 (led by STFC), comprises the identification and analysis of potentially-geoeffective solar-wind events that are observed by both the Heliospheric Imager (HI) and IPS.  Task 7.2 (led by IMPERIAL), comprises the identification, analysis and cataloguing of solar wind transients that are observed by both HI and in Type II radio burst emission, principally detected by the STEREO/WAVES instruments.  This work package is now well underway. In particular, since the 12 month report a postdoctoral research associate has been hired at IMPERIAL to work exclusively on the HELCATS project and WP7 in particular (Vratislav Krupar, start date 1 July 2015. Krupar has considerable prior experience in the analysis of radio data). Regarding Task 7.1, work effort has focused on the cataloguing and development of new and improved software to assist analysis. Regarding Task 7.2, the analysis of a detailed case study has already been completed and is being prepared for publication. This has enabled the foundations of the approach to cataloguing the data to be established, and this process is now well underway. |
| WP7 TASK 7.1: IDENTIFYING AND ANALYSING POTENTIALLY GEOEFFECTIVE SOLAR WIND EVENTS THAT ARE OBSERVED BY BOTH HI AND IPS (TASK LEAD: STFC)  Work on this task has been performed by STFC (Bisi/Barnes). As previously noted, It should first be recognised that IPS data are not uniformly available (the radio-telescope systems used here run on a campaign basis only for observations of IPS) and so it is first necessary to establish the data availability working from the catalogues of CMEs and CIRs/SIRs provided by WP2 and WP5, respectively.  Cataloguing   1. As a first accomplishment, all the EISCAT IPS data for the STEREO era have now been sorted. Bad and/or problematic observations have been sifted and removed. 2. Approximately half of the STEREO era data has been analysed with the UCSD IPS tomography. However, this has made use of an older version of the software. It is intended to run it for the entirety of the STEREO era with the most-up-to-date versions of the CAT and the visualisation routines (see below). 3. The IPS analyses program enables all of the available data to be analysed using an automated mode which finds the CME events. This is in progress. Also ongoing is planning for how to best address the SIR aspects of Task 7.1 (using ideas and approaches based on that used in Bisi et al., Solar Physics, 2010).   With a data catalogue now coming online, work is now focusing on the development of new software that can be used to batch process the event list and thus make efficient progress in pursuit of the overall project goals.  Software development   1. For example, the IDL scripts for directly plotting the IPS P-Point into the STEREO HI field of view have been rewritten and now run much more simply via the updated geometrical routines available in SSW-IDL. This is superior to various ad hoc work-around scripting that has previously been used by e.g. Dorrian et al. and Hardwick et al. 2. More generally, the porting of the IPS data-analyses cross-correlation package to new processing machines at STFC has in fact proved more problematic than originally anticipated. These issues were of a technical and/or computational nature. Most have now been resolved with final testing currently ongoing. 3. Enhancing software is also being developed. A script for finding the CME (negative-lobe) signatures in a systematic way from the analysed cross-correlation EISCAT data is being developed. 4. In collaboration with B. Jackson (UCSD), the latest IDL visualisation routines for tomography are being implemented at STFC, supplemented by discussions and meetings arranged in conjunction with the Third Remote Sensing of the Inner Heliosphere & Space Weather Applications Workshop in Mexico.   Presentations at international meetings and conferences:  Third Remote Sensing of the Inner Heliosphere & Space Weather Applications Workshop, Morelia, Mexico, 20-24 October 2015 |
| WP7 TASK 7.2: IDENTIFYING AND ANALYSING SOLAR WIND TRANSIENTS THAT ARE OBSERVED BY BOTH HI AND IN TYPE II RADIO BURST EMISSION (TASK LEAD: IMPERIAL; ADDITIONAL PARTICIPANT: ROB)  As previously described, the goals of this task are to develop a joint catalogue of CMEs observed in HI, and S/WAVES and Wind/WAVES data, extending the catalogue with ground-based radio observations to examine more closely the source region of each CME. Height-time statistics will then be constructed, and the usefulness of radio data in constraining modelling of CME lift-off will be systematically studied. Interacting CME events will be explored in detail to examine how radio data can be used to decipher event kinematics and improve forecasting.  The initial effort has focused on two parallel activities; a detailed case study of a specific event which is very well observed, and construction of the foundations of the radio catalogue.  Case study: To fully understand the complementary nature of radio observations, we have focussed on a specific CME in the time interval 29 November – 1 December 2013. This event produced strong radio emission that was detected by both STEREO spacecraft, allowing direction finding techniques to be deployed [Krupar et al., 2012]. Furthermore, the CME was imaged in HI, and was directed so that it passed over the MESSENGER spacecraft at Mercury, before being intercepted by STEREO-A. This event therefore affords comprehensive insight into CME physics, with remote optical, radio and in situ plasma data at multiple points being available. It cuts across essentially all of the HELCATS work packages. This event analysis has been performed by IMPERIAL (Krupar/Eastwood) with input from ROB (Magdalenic), and has called on other partners working in particular on WP2 and WP3 as described in more detail below.  The kinematic properties of the CME have been studied in four independent ways:   1. Radio data have been used to construct height/time profiles based on density modelling and also triangulation using the radio data from both stereo spacecraft together 2. HI data and height/time information contained in the WP2 catalogue for this event (with input from STFC (Davies/Barnes/Byrne)) 3. In situ measurements of CME shock arrival time at STEREO-A and MESSENGER (with input from WP4 IMPERIAL (Forsyth/Good)) 4. coronagraph images have been used to determine height/time and therefore speed profiles: we have examined output of the automated SEEDS algorithm and also compared to the Graduated Cylindrical Shell model (WP3 input from GOTTINGEN (Bothmer/Pluta/Mrotzek))   Several important conclusions have been revealed. The first is the overall very good agreement between the GCS modelling, the radio data (based on density model), the HI data and the in situ detection. This is illustrated in Figure 1 (Krupar et al., in preparation, 2015). By combining Coronagraph, HI, radio and in situ, this work demonstrates in new detail how radio data can be used to accurately profile the height/time behaviour of a CME, and therefore how radio data could possibly be used in the absence of other data to estimate CME properties and constrain models of CME lift-off. The disagreement between the direction finding and the density model radio height/time profiles is most probably due to refraction of signal which requires further investigation. The good agreement between the radio and GCS, but disagreement with SEEDS, shows that radio data analysis may provide rapid and accurate insight into the dynamics of the CME at lift-off. This event also illustrates an important link to WP4, with in situ observations. The results of this case study are now being prepared for publication, and are to be submitted to Astrophysical Journal Letters.  The results of the case study have informed the approach to constructing the radio catalogue, as we now describe.  Catalogue: As a first step, the WP2 catalogue was used to establish an appropriate event time list. Associated summary plots of STEREO and Wind radio data were then generated. Each summary plot corresponds to a 24 hour interval of data centred on the HI event time. However, as shown in Figure 1, the radio data frequency range corresponds to heights which are typically inside the HI field of view. It was therefore very difficult to precisely determine which signatures in the radio data should be associated with the HI data, especially if there was significant Type III emission from flaring.  This led to a more direct comparison with coronagraph imaging – again as illustrated by the case study, it is clear that coronagraph data provides contemporaneous optical information about the CME when compared to the radio data. We are using the output of WP3, and in particular the CME catalogue that was made available by GOTTINGEN <http://www.affects-fp7.eu/helcats-database/database.php> to combine this data with the radio data overview plots, and establish more precisely the association of different features with different events. This task has proved somewhat complex, but progress has been aided by the willing assistance of those working on WP2 and WP3.  It is worth noting that the WP3 catalogue only contains a fraction of all the CMEs observed by STEREO, as it focuses on those events that are sufficiently bright so as to be analysed with the GCS modelling technique. Most recently we have started to use the entire CME list (e.g. <http://sidc.oma.be/cactus/> ) which is automatically generated in order to gain some insight into the radio properties of the dataset associated with the entire STEREO mission. This work is currently ongoing. Other continuing work tasks include establishing the parameters that should be included in the radio data catalogue, and the technical implementation of the catalogue on the HELCATS website.    *Figure 1: results of height/time analysis for the CME observed between 29 November – 1 December 2013 [Krupar et al., manuscript in preparation, 2015]. The height/time profile is determined using a variety of independent techniques. The green squares show the result of GCS modelling applied to coronagraph images. The purple triangles show the results derived from radio data applying a density model. The cyan diamonds show the output of the HI data from WP2. The yellow and red squares correspond to the observations made in situ by MESSENGER and STEREO-A. The blue crosses show the results of the radio direction finding. It can be seen that the observations made by multiple spacecraft, using remote and in situ measurements were able to track the CME all the way from the corona to 1 au. In particular, the radio data bridges the gap between the corona and interplanetary space (as observed by HI). Therefore in the absence of one or more of the optical datasets, it would still be possible to predict arrival times at 1 au.*  Presentations at international meetings and conferences:  National Astronomy Meeting, Llandudno, Wales, 5-9 July 2015  Solar Orbiter/Solar Probe Plus Meeting, Florence, Italy, 2-4 September 2015 |
| WP7 SUMMARY/NEXT STEPS: In the next 12 months:  7.1: It is expected that good progress to a complete and consistent analysed data set of the available EISCAT/ESR and LOFAR IPS data throughout the STEREO mission period to date will be made. Issues pertaining to software reliability are expected to be rapidly resolved, and the development of enhancing software is underway. By the end of the calendar year it is anticipated that the IPS-ENLIL code will be updated whereby the current small errors in solar rotation will be corrected as well as enhanced visualisation routines. More generally, effort is expected to focus on cataloguing in the first instance through the first half of 2016. Two case studies have been identified that may also bear significant insight and these will also be pursued as a secondary objective. Complex interacting CME events will also be identified as targets for future study in the final part of the project.  7.2: The results of the first case study are now being prepared for publication. It is expected that this will be submitted by the end of the calendar year, and published in early 2016. An abstract to present the work at the Fall AGU meeting in San Francisco, USA, has been accepted and this will take place in December 2015. Work to complete the catalogue is ongoing. It is expected that the first version of the catalogue will be available in early 2016. At this point, it is anticipated that initial top-level statistics concerning occurrence, duration, brightness *etc*. will be available for review by month 24 of the project. This will follow on to an assessment of which CMEs are most radio-loud, and initiate an exploration in more detail of why this is the case. It will also enable the selection of case studies consisting of interacting CME events. |