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Acronym List

AMDA Automated Multi-Dataset Analysis (software tool)

CIR Co-rotating Interaction Region

CME Coronal Mass Ejection

CNRS Centre National de la Recherche Scientifique

EUV Extreme UltraViolet

GCS Graduated Cylindrical Shell model

GMU George Mason University

HELCATS Heliospheric Cataloguing, Analysis and Techniques Service

HI Heliospheric Imager/Imaging

ICME Interplanetary CME

IMPERIAL Imperial College of Science, Technology and Medicine, London

IPR Intellectual property rights

IPS Interplanetary Scintillation

MGT Management

MHD Magnetohydrodynamics

ROB Koninklijke Sterrenwacht van Belgie

RTD Research and Technology Development

RAL Rutherford Appleton Laboratory

OTH Other

SIR Stream Interaction Regions

STEREO Solar Terrestrial Relations Observatory (mission)

STFC Science and Technology Facilities Council

TCD The Provost, Fellows, Foundation Scholars & the other members of Board of the College of the Holy and Undivided Trinity of Queen Elizabeth near Dublin

UGOE Georg-August-Universitaet Goettingen Stiftung Oeffentlichen Rechts

UH Helsingin Yliopisto

UNIGRAZ Universitaet Graz

UPS Universite Paul Sabatier Toulouse III

WP Work Package

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# Introduction

The advent of wide-angle imaging of the inner heliosphere has revolutionised the study of the solar wind and, in particular, transient solar wind structures such as Coronal Mass Ejections (CMEs) and Co-rotating Interaction Regions (CIRs). CMEs comprise enormous plasma and magnetic field structures that are ejected from the Sun and propagate at what can be immense speeds through interplanetary space, whilst CIRs are characterised by extensive swathes of compressed plasma/magnetic field that form along flow discontinuities of solar origin that permeate the inner heliosphere. With Heliospheric Imaging (HI) came the unique ability to track the evolution of these features as they propagate through the inner heliosphere. Prior to the development of wide-angle imaging of the inner heliosphere, signatures of such solar wind transients could only be observed within a few solar radii of the Sun, and in the vicinity of a few near-Earth and interplanetary in-situ probes. HI has, for the first time, filled that vast and crucial observational gap.

The HELCATS project provides an unprecedented focus for world-leading European expertise in the novel and revolutionary, European-led field of HI, in terms of instrumentation, data analysis, modelling and science. HELCATS is a strategic project that empowers the wider scientific community, in Europe and beyond, by providing access to advanced catalogues - validated and augmented through the use of techniques and models - for the analysis of solar wind transients, based on observations from European-led space instrumentation. All beneficiaries are at the forefront of heliospheric research and bring distinct, yet highly complementary, skills to the project. HELCATS adds significant value to the exploitation of existing European space instrumentation, providing a strong foundation for enhanced exploitation and advancement of European heliospheric research.

HELCATS recognises the synergy between solar and heliospheric physics research (both of which are European strengths) and their applied space weather aspect, currently a topic of vigorous debate in many political and scientific arenas. With the impending development of a European space weather capability, HELCATS has real, practical relevance.

The HELCATS consortium is led by STFC’s Rutherford Appleton Laboratory. The Coordinator is Professor Richard A Harrison, the Scientific Manager is Dr Jackie A Davies and the Technical Manager is Dr Jason P Byrne. The list of beneficiaries is given in Table 1. The HELCATS workpackage (WP) structure is given in Table 2.

*Table 1: HELCATS Beneficiaries*

|  |  |  |  |
| --- | --- | --- | --- |
| No | NAME | SHORT NAME | COUNTRY |
| 1 | SCIENCE AND TECHNOLOGY FACILITIES COUNCIL | STFC | United Kingdom |
| 2 | UNIVERSITAET GRAZ | UNIGRAZ | Austria |
| 3 | UNIVERSITE PAUL SABATIER TOULOUSE | UPS | France |
| 4 | GEORG-AUGUST-UNIVERSITAET GOETTINGEN STIFTUNG OEFFENTLICHEN RECHTS | UGOE | Germany |
| 5 | KONINKLIJKE STERRENWACHT VAN BELGIE | ROB | Belgium |
| 6 | IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE | IMPERIAL | United Kingdom |
| 7 | HELSINGIN YLIOPISTO | UH | Finland |
| 8 | THE PROVOST, FELLOWS, FOUNDATION SCHOLARS & THE OTHER MEMBERS OF BOARD OF THE COLLEGE OF THE HOLY & UNDIVIDED TRINITY OF QUEEN ELIZABETH NEAR DUBLIN | TCD | Ireland |

*Table 2: The HELCATS WP structure*

|  |  |  |
| --- | --- | --- |
| WP No | WP ACTIVITY TYPE | WP TITLE |
| 1 | MGT | MANAGEMENT |
| 2 | RTD | PRODUCING A DEFINITIVE CATALOGUE OF CMES IMAGED BY STEREO/HI |
| 3 | RTD | DERIVING/CATALOGUING THE KINETIC PROPERTIES OF STEREO/HI CMES BASED ON GEOMETRICAL AND FORWARD MODELLING |
| 4 | RTD | VERIFYING THE KINEMATIC PROPERTIES OF STEREO/ HI CMES AGAINST IN-SITU CME OBSERVATIONS AND CORONAL SOURCES |
| 5 | RTD | PRODUCING A DEFINITIVE CATALOGUE OF CIRS IMAGED BY STEREO/HI THAT INCLUDES VERIFIED MODEL- DERIVED KINEMATIC PROPERTIES |
| 6 | RTD | INITIALISING ADVANCED NUMERICAL MODELS BASED ON THE KINETIC PROPERTIES OF STEREO/HI CMES AND CIRS |
| 7 | RTD | ASSESSING THE COMPLEMENTARY NATURE OF RADIO MEASUREMENTS OF SOLAR WIND TRANSIENTS |
| 8 | OTHER | DISSEMINATION |

This 18 month report is broken down into reports from each WP. Thus, to aid the reading of these WP reports, we repeat the WP strategy and structure details here, and refer the reader to the WP structure diagram.

The fundamental aim of the HELCATS project is to start with heliospheric imaging observations and, from that, build up facilities, methods and assessment studies in a logical programme of activities. The work is managed by STFC, involving a total of eight European research groups. The activities of the groups are tailored to their scientific and technical strengths, maximizing the potential scientific return for the project.

**WP1:** **Management** - The consortium includes 8 European groups from 7 EU countries and 2 third parties. The project coordinates work involving observations, cataloguing, modelling, and studies in validation and assessment. WP1 covers the formal management roles of the HELCATS project. This includes administrative tasks, maintaining project infrastructure, coordinating inputs and reporting as required and handling a range of project issues. WP1 oversees the website production and management.

**WP2:** **Producing a definitive catalogue of CMEs imaged by STEREO/HI** - This WP provides the foundation for this project (including scientific coordination), namely the production of a catalogue of CMEs in the heliosphere. The catalogue is produced from manual inspection of STEREO/HI data but use of automated techniques are being investigated. Comparisons with coronal CME catalogues are being made.

**WP3: Deriving/cataloguing the kinematic properties of STEREO/HI CMEs based on geometrical and forward modelling** - Here we apply recently established geometrical, forward and (prototype) inverse modelling methods to derive CME parameters, which will be added to the catalogue (including back- and forward-projections to ‘predict’ CME launch and arrivals at various solar system locations). Comparisons will be made between the parameters yielded by the different models.

**WP4: Verifying the kinematic properties of STEREO/HI CMEs against in-situ CME observations and coronal sources** - This WP catalogues in-situ CME information (at Earth and elsewhere) for comparison to the projected data from WP3 in order to assess the performance of the aforementioned models. Similarly, comparisons are made with solar ‘surface’ phenomena. These allow a thorough validation of the models.

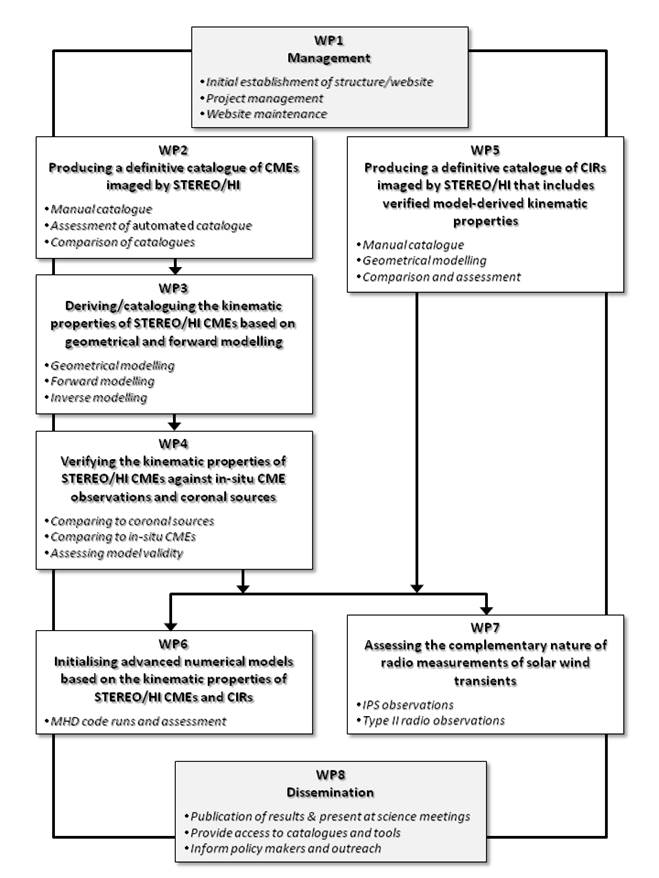
**WP5: Producing a definitive catalogue of CIRs imaged by STEREO/HI that includes verified model-derived kinematic properties** - In parallel with the CME cataloguing, modelling and model assessment in WP2-4, this WP performs an analogous activity for CIRs, again with cataloguing, geometrical modelling and the validation of results through comparisons to in-situ/solar data.

**WP6: Initialising advanced numerical models based on the kinematic properties of STEREO/HI CMEs and CIRs** - This WP recognises the potential for using HI data as input to numerical MHD models of the heliosphere (in terms of both CME and CIR phenomena) by considering the use of HI images for initialisation/driving of the ENLIL model. The results will be compared to traditional methods for running such models, based on coronal and photospheric inputs, to assess their potential.

**WP7: Assessing the complementary nature of radio measurements of solar wind transients** - WP7 explores the value of incorporating radio observations, to augment the HI data. It assesses the value of using interplanetary scintillation (IPS) observations and Type II radio burst data in conjunction with HI data, both of which can provide additional information.

**WP8: Dissemination** - WP8 brings the results to the community through (1) the publication of results in the open, refereed literature, (2) the running of annual open meetings, (3) the installation of all relevant documentation, catalogues and reports on the website and (4) the dissemination of information to the public and policy makers. This includes ingestion of the products into the AMDA data-mining tool the IRAP (UPS) propagation tool, and integration with projects such as HELIO. This WP coordinates the exploitation of the project outputs, such that they feed into numerous research activities and future space weather applications.

Overall, the HELCATS strategy is to coordinate a range of observational and modelling studies of heliospheric phenomena to provide a foundation for enhancing the scientific discipline and the exploitation of European investment in the hardware involved.



Full details of the HELCATS project can be seen in the description of work documents (606692\_DOW\_PART\_A.pdf and 606692\_DOW\_PARTB.pdf) agreed with the European Commission in early 2014. The project kicked-off in May 2014. The distribution of work, divided by beneficiary and by WP is given in Table 3.

*Table 3: The distribution of work between beneficiaries and WP*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Beneficiary** | **WP1** | **WP2** | **WP3** | **WP7** | **WP4** | **WP5** | **WP6** | **WP8** | **Total per Beneficiary** |
| 1 – STFC | 8.50 | 25.00 | 9.00 | 19.50 | 0.00 | 0.00 | 0.00 | 11.50 | 73.50 |
| 2 - UNIGRAZ | 0.00 | 0.00 | 6.00 | 0.00 | 30.00 | 0.00 | 0.00 | 0.00 | 36.00 |
| 3 – UPS | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 25.00 | 24.00 | 10.00 | 61.00 |
| CNRS | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 8.00 | 3.00 | 0.00 | 13.00 |
| 4 – UGOE | 0.00 | 6.00 | 21.00 | 0.00 | 12.00 | 0.00 | 0.00 | 0.00 | 39.00 |
| 5 – ROB | 0.00 | 20.50 | 0.00 | 3.00 | 6.00 | 0.00 | 0.00 | 0.00 | 29.50 |
| 6 - IMPERIAL | 0.00 | 0.00 | 0.00 | 17.00 | 3.00 | 0.00 | 0.00 | 0.00 | 20.00 |
| 7 – UH | 0.00 | 0.00 | 0.00 | 0.00 | 13.00 | 9.00 | 0.00 | 0.00 | 22.00 |
| 8 – TCD | 0.00 | 0.00 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 |
| **Total** | 8.50 | 51.50 | 51.00 | 39.50 | 68.00 | 42.00 | 27.00 | 21.50 | 309.00 |

In the following pages we address each WP in turn, providing a summary of the WP activities and an update of progress and next steps. HELCATS is a three-year project and we are 18 months into the activities. The project has a clearly defined schedule of activities, milestones and deliverables and this report demonstrates that the project is on schedule. The WP summaries have been produced by the WP leaders; this does mean that the reports vary slightly in style and format. However, the aim is to produce a thorough statement on the status of the project and the future steps, and this, we believe has been done effectively.

# Work Package Summaries and Reports

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| WORK PACKAGE 1 (WP1):  MANAGEMENT |
| WP1 ACTIVITY TYPE: MGT |
| WP1 DURATION: MONTHS 1 – 36 |
| WP1 LEAD BENEFITIARY: STFC (1) |
| WP1 LEADER: Professor Richard A Harrison |
| WP1 CONTRIBUTORS: n/a |
| WP1 OVERVIEW: The main tasks of WP1 are the initial establishment of the management structure for the HELCATS project, and its support and communication tools, the general operation of this structure, and its termination at the end of the project together with the delivery of the final reports. The work package consists of two tasks, namely, the HELCATS Project Management and the HELCATS website maintenance. The HELCATS consortium consists of 8 European groups (involving 7 EU counties), plus one third-party group from the USA. The project is a complex coordination of activities involving observations and cataloguing, techniques, the development of models and their application, and exercises in validation and assessment. The objective of WP1 is to provide the necessary management structure to implement the HELCATS project effectively, overseeing all administrative matters, assembling and submitting formal reports, overseeing finance auditing, and arranging meetings as appropriate. WP1 will oversee the scheduling and progress of all activities, and the production and management of the HELCATS website. |
| WP1 TASK 1.1: HELCATS PROJECT MANAGEMENT (TASK LEAD: STFC)  Task 1 covers the formal management roles of the HELCATS project. This includes administrative tasks, maintaining project infrastructure, coordinating inputs and reporting as required and handling a range of project issues.  At the onset of the project, the Executive Board established the formal communication with the Steering Committee, setting up monthly teleconferences and the kick off meeting. The first draft of the HELCATS website was released. The kick off meeting was held on 14-15 May 2014, hosted at the STFC Rutherford Appleton Laboratory. It was attended by all of the beneficiaries and the EU Project Officer. All WPs were discussed in detail. The meeting schedule and locations, for the Bi-Annual Project Meetings/Workshops and the Annual open Workshops were decided for the entire period of the project, ensuring that most beneficiaries hosted at least one meeting. The website was also discussed in detail and formally released (<http://www.helcats-fp7.eu/>) after the kick-off meeting. Minutes of the meeting and of all subsequent teleconferences are placed on the website (meeting reports are openly available through a ‘meetings’ tab, under the ‘News’ item; teleconference minutes are held within the project wiki on the same website.  Thus, after the kick-off meeting, the project satisfied the first two deliverables:  D1.1 – HELCATS website launch (delivery date by month 3)  D1.2 – Minutes of the kick-off meeting (delivery date by month 2)  WP progress is discussed at each monthly telecon with the Steering Committee, chaired by the Coordinator or the Scientific and Technical Manager.  The first Biannual Meeting of the project was held a ROB on 5-6 November 2014. WP progress was discussed by the Steering Committee; the meeting details and report were lodged on the HELCATS website (under the ‘Meetings’ tab). Technical issues relating, in particular, to standards for the cataloguing activities were addressed in some detail due to the increasing cataloguing activities of the WPs.  The Annual Open Workshop and second Bi-annual Meeting of the project have been arranged for the week of the 18th to 22nd of May 2015, hosted at Göttingen, Germany, with the arrangements being led by the HELCATS Coordinator, Scientific and Technical Manager, and the UGOE host (Professor Volker Bothmer), reporting to the Steering Committee. Again, at the Bi-Annual Meeting component of the meeting, the progress of each WP will be reported and any technical issues discussed in detail.  Through this WP, the project maintains contact with the EU through the Project Officer and deals with any formal project communications. We coordinate the production of required documentation and oversee meetings with support for logistical arrangements, information; we set the agendas for meetings and have responsibility for overseeing any formal aspects of the project, if required, such as any legal issues or changes to the project structure (e.g. due to staff changes). However, to date, the basic structure of the project and the progress of the WPs have been established and delivered as planned. |
| WP1 TASK 2.1: HELCATS WEBSITE MAINTENANCE (TASK LEAD: STFC)  The HELCATS website is used for both internal circulation of information and external dissemination of the projects aims and objectives. All documents are available to all members of the consortium, during the whole project, on the private part of our website. The Project Coordinator has the responsibility to maintain and update the website at least every 2 weeks. Products of the project, such as the catalogues and reports, will be openly available through the website, after their delivery. Note that the Dissemination workpackage, WP8, has responsibility for placing reports, catalogues, publications etc… on the website. |
| WP1 SUMMARY/NEXT STEPS:  WP1 continues throughout the lifetime of the HELCATS project, overseeing all formal communications, meetings, and the project coordination. Thus, the Steering Committee teleconferences will continue on a regular basis, the Bi-Annual and Annual meetings will proceed as planned and scheduled throughout the project, and reports will be produced as required. After the Göttingen meetings, in addition to the WP progress, with regard to deliverables, the emphasis will be on the next Bi-Annual meeting in the autumn of 2015 in Helsinki, Finland, and production of the 18 month progress report to the Commission, which will be the first major financial report. |

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| WORK PACKAGE 2 (WP2):  PRODUCING A DEFINITIVE CATALOGUE OF CMES IMAGED BY STEREO/HI |
| WP2 ACTIVITY TYPE: RTD |
| WP2 DURATION: MONTHS 1 – 36 |
| WP2 LEAD BENEFITIARY: STFC (1) |
| WP2 LEADER: Dr Jackie Davies |
| WP2 CONTRIBUTORS: UGOE (4); ROB (5) |
| WP2 OVERVIEW: WP2 involves the production of a catalogue of CMEs in the heliosphere through visual inspection of white-light imagery from the HI Instruments on NASA’s twin-spacecraft STEREO mission. Autonomous cataloguing of STEREO/HI CMEs, based on use of the long-established CACTus software package, has also been investigated within this WP, and since it has proved to be successful, these catalogues are currently being compared with each other, as well as with other, pre-existing, coronal CME catalogues. WP2 is divided into four tasks. Task 2.1 (led by STFC) comprises the manual CME cataloguing of STEREO/HI CMEs, while the automatic cataloguing is performed under Task 2.2 (led by ROB); Task 2.3 (led by UGOE) covers the comparison of the resultant CME catalogues, both with each other and pre-existing coronal CME catalogues. Task 2.4 (led by STFC) covers the HELCATS scientific management. A summary of the progress in each of these tasks, over the first 18 months of the HELCATS project, is given below. |
| WP2 TASK 2.1: MANUAL CATALOGUING OF STEREO/HI CMES (TASK LEAD: STFC)  Work Package 2 (WP2) is core to the HELCATS project, in that it provides the fundamental manually-generated coronal mass ejection (CME) catalogue on which the subsequent CME-oriented WPs, such as WP3, are based. It is generated by the visual inspection of heliospheric images from the STEREO/HI-1 observations, from the start of the mission science phase in April 2007. Through extensive discussion within the HELCATS consortium, the format of the manual CME catalogue (Task 2.1 of WP2) contains the following six fields:  *•* A unique CME identifier.  *•* The time of first observation of the CME in the HI-1 field of view (UTC).  *•* The observing spacecraft (A or B).  *•* The northernmost position angle extent of the CME (degrees).  *•* The southernmost position angle extent of the CME (degrees).  *•* A quality flag indicating whether the CME observation is considered *poor*, *fair* or *good*.  The unique CME identifier is a string containing both the date on which the CME is first observed in HI-1 and the observing spacecraft, with an additional two-digit number to differentiate between multiple CMEs occurring on the same day. So, for example, a CME observed by STEREO-A on 31 Dec. 2007 will have the identifier “HCME A 20071231 01”. CMEs that exceed the position angle range of the field of view are indicated with a *greater than “>”* or *less than “<”* symbol in the appropriate field. It should be noted that in recognition of the numerous blob-like transients observed close to the Sun, for the unambiguous identification of CMEs, we demand that CMEs have position angle widths of 20o or more. The quality flag has been introduced to account for the ambiguity that results from using human observers to identify events. This field is used as a means to quantify the confidence of the observer, based on the following criteria. A *poor* event is any object (spanning at least 20*◦* in position angle, as noted), but which poorly resembles a CME. A *fair* event is one that resembles a CME, though not all observers may be convinced that this is the case (due to some limitation in the event observation such as a faint, disjoint or otherwise irregular CME structure). A *good* event is one that is unquestionably a CME.  18 month update: This cataloguing has been completed for the full nominal STEREO mission science phase, years 2007*−*2014, providing the observational properties of over 1000 events.    *Figure 2.1: The WP2 HI catalogue facility on the HELCATS website*  Figure 2.1 shows a snapshot of the HI catalogue facility that resides on the HELCATS website (www.helcats-fp7.eu), under the ‘products’ tab. The catalogue is updated as events are identified and inspected. The facility includes a capability to select date ranges and specific position angle location and width. |
| WP2 TASK 2.2: AUTOMATIC CATALOGUING OF STEREO/HI CMES (TASK LEAD: ROB)  In addition to manual CME identification, WP2 (Task 2.2) also comprised an assessment of the potential of autonomous detection of CMEs in the STEREO/HI imagery using ROB’s CACTus software application (http://sidc.oma.be/cactus/). CACTus, a long-established algorithm for automatic CME detection and tracking, has, in the past, been applied exclusively to coronagraph images, from SOHO/LASCO and STEREO/COR.  CACTus (http://sidc.oma.be/cactus/), a long-established algorithm for automatic CME detection and tracking, has, been successfully adapted to work with STEREO-HI images. Before HELCATs, CACTus was only working with coronagraph images from SOHO-LASCO and STEREO-COR instruments. CACTus applies the Hough transform to distance – time maps, which are then converted to a time vs angle map which contains all information about the CME (see Robbrecht and Berghmans 2004 for more details). This information includes the starting time of the CME, its position angle, angular width and speed.  The catalogue covers the full STEREO mission and looks like in the following figure:  *Figure 2.2: A sample of the CACTus catalogue for the HI data.*  In the left panel each CME is marked with a number and the following columns describe the CME parameters, measured automatically. On the right panel, a graphic version of the detections is shown. The user can click on each CME to obtain further details of the event, including movies.  In order to validate the catalog, we are currently doing comparisons with the manual catalog from Task 2.1. We have identified the events that are common to both catalogues, this was done via an algorithm that compares starting times of CMEs, their direction of propagation and angular widths. We are currently comparing their characteristics, in order to see where the differences are between manual and automatic classification. Furthermore, we have started to do an eye inspection of all the events and to do a manual matching between both catalogs. The outcome of this analysis will help to do a fine-tuning of the parameters in the automatic detection algorithm, and also provide physical insights into the properties of the CMEs detected in HI data. |
| WP2 TASK 2.3: COMPARISON OF CME CATALOGUES (TASK LEAD: UGOE)  A UGOE STEREO/SECCHI/COR2 CME-database was established under the framework of the DLR project STEREO/Corona, the EU FP7 project SOTERIA and continued in the EU FP7 projects AFFECTS. This COR2 database, available online at http://www.affects-fp7.eu/cme-database/, has been updated to cover the period to the end of 2011. Based on clarity of the CME topology in the COR2 field of view (2.5 – 15 Rs) during the time interval 2007-2011, out of a total number of 1071 events, 241 were selected for further analyses, e.g. for applying the Graduated Cylindrical Shell (GCS) modelling method. These events are referred to as being on the STEREO COR2 “Best-of-list”. The COR2 “Best-of-list” is being compared with the STEREO/SECCHI/HI1A and B preliminary lists established under WP2 task 2.1. The HI1 A preliminary list contains a total of 821 events for the investigated time interval, the HI1 B list contains a total of 698 events. Comparison of the HI lists with the COR 2 “Best-of” list has yielded a set of 109 CME events that could be uniquely associated in both the HI1A or B and COR2 A or B fields of view without duplicate events. A sample event to which GCS-modelling has been applied in both fields of view is shown in Figure 2.1 for illustration. The comparison lists will be made available at the HELCATS website.    *Figure 2.1: Sample CME observed in the STEREO/SECCHI/COR2 and HI1 A and B fields of view on April 03, 2010. The green grids are the CME GCS-fits.* |
| WP2 TASK 2.4: SCIENTIFIC MANAGEMENT (TASK LEAD: STFC)  Whereas WP1 covers the administrative management of the HELCATS project, WP2 includes an element for the scientific and technical management. Thus, whereas WP1 includes aspects such as the oversight of the meeting and teleconference structure, the WP2 effort coordinates the scientific and technical discussion between the WP leaders and the wider team. Throughout the project activities to date, this has focused on the teleconference discussions, the kick-off and six monthly meetings and the technical details of the report writing; it also covers the regular technical communication with the WP teams on a range of issues as the project progresses. Thus, this WP runs in parallel with the logistical management of the project and continues throughout the HELCATS project. It is coordinated by the Scientific and Technical Manager. |
| WP2 SUMMARY/NEXT STEPS:  The activities of WP2 are well underway, with active cataloguing of HI events, both by manual inspection and by automated processes. In addition, comparisons to coronagraph catalogues are being made. Many of the WP2 activities continue throughout the HELCATS project; the final catalogue deliverables are actually required by month 36 (deliverables D2.1, D2.5). This is a natural consequence of the fact that the STEREO project is still in operation and the event lists will grow throughout the mission. However, there are three deliverables that have been finalised so far: Deliverable D2.1 which is the observational cataloguing of CMEs in the HI images, now complete for 2007 to late 2014; Deliverable D2.2 which is the report on the feasibility of automated CME identification that has indeed been demonstrated; and Deliverable D2.3 which is the report on the comparison of the manual and automated catalogues. In summary, the cataloguing activities are progressing as planned. |

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| WORK PACKAGE 3 (WP3):  Deriving/cataloguing the kinematic properties of STEREO/HI CMEs based on geometrical and forward modelling |
| WP3 ACTIVITY TYPE: RTD |
| WP3 DURATION: MONTHS 1 – 36 |
| WP3 LEAD BENEFITIARY: UGOE (4) |
| WP3 LEADER: Dr. Volker Bothmer |
| WP3 CONTRIBUTORS: UGOE (4); TCD (9); STFC (1); UNIGRAZ (2) |
| WP3 OVERVIEW: The key objectives of WP3 are deriving and cataloguing the kinematic properties of the STEREO/HI CMEs identified and catalogued in WP2, based on geometrical and forward modelling. For these purposes the recently established geometrical, forward (and prototype) inverse CME-modelling methods are applied. The CME parameters will be added to the catalogue, including back- and forward-projections to ‘predict’ CME launch and arrivals at various solar system locations. Comparisons will be made between the parameters yielded by the different models. |
| WP3 TASK 3.1: Geometrical modelling of STEREO/HI CMEs (TASK LEAD: STFC)  The STFC contribution to WP3 is principally through Task 3.1, the geometrical modelling of STEREO/HI CMEs. This task involves the derivation of the kinematic properties of those CMEs visually identified in WP2.1. This is achieved by selecting the track made by each CME in a time-elongation map (J-map) and applying the assumptions about its geometry and dynamics summarized in Davies et al. (2012, *Astrophys. J*., 750, 23). This makes use of three established geometrical approaches, assuming that the CME can be modelled (i) as a point-like feature propagating outwards (known as the Fixed Phi method), (ii) as an expanding circle whose diameter is defined by the CME apex and Sun-centre (known as the Harmonic Mean method), and (iii) as a self similarly expanding circle propagating outward between two fixed position angles (known as the Self Similar Expansion method).  The CMEs are assumed to travel at a constant speed in a fixed. The three different fitting methods are applied to each CME (see Davies et al., for details). For a given CME, the path of its (apparent) leading edge through a J-map is manually tracked at a position angle close to its apex and each of the three fitting procedures is applied to estimate its 3D speed and propagation direction. These values are, in turn, used to derive launch times for each event, which are then applicable to WP4.1, and to generate arrival times at various locations in the heliosphere for comparison with in-situ measurements (WP4.2).  To date, events occurring during the odd-numbered years for both STEREO-A and -B have been analysed in this way. Events identified as poor in WP2.1 are excluded, as are those which are directed at position angles far from the ecliptic, due to the limited number of HI frames in which they appear. A number of small CMEs occur, which quickly become subsumed by subsequent, larger events; these events are also excluded. This process has been completed for a total of 622 events; 323 for STEREO-A and 299 for STEREO-B. Distributions of the speeds of these CMEs are shown in Figure 3.1, separated according to year, spacecraft and fitting technique.  The catalogue of geometrically modelled STEREO/HI CMEs generated in task 3.1 is used by UNIGRAZ to derive a catalogue of CME arrival time estimates at Mercury, Venus, Earth, Mars and Saturn, providing support to European-funded space missions around these planets. Predicted arrivals at the Ulysses spacecraft location are also made. Using initial speeds and directions from the geometrically modelled CME catalogue provided by STFC, UNIGRAZ has applied the Self-Similar Expansion Model results with the correction formulae of Möstl & Davies (2013, *Solar Phys.* 285, 411), which takes into account the angle between geometrically fitted CME initial speed and direction and the planetary in-situ location, to derive estimates of CME arrival time (Fig 3.2).    *Figure 3.1: Distributions of the speeds of the modelled CMEs, separated according to year, spacecraft and fitting technique (Fixed Phi Fit (FPF), Self Similar Expansion Fit (SSEF), Harmonic Mean Fit (HMF)).*    *Fig. 3.2: SSEF ICME speed vs. Transit time to different planetary locations.*  This model also allows one to estimate whether, and to what degree, each CME will ‘hit’ any in-situ location, and this is provided as a parameter in the catalogue, along with speeds and arrival times. A user friendly package in the IDL programming language has been created to read in the geometrically modelled CME catalogue files and output the predicted arrival time files (Figure 3.3) for any of the in situ locations. The initial catalogue contains over 400 predicted arrivals at Earth, and over 100 for Mercury-, Venus-, Mars- and Saturn-directed CMEs. The arrival times will be compared to other model results and in situ data in WP4.    *Fig. 3.3 Sample Arrival Time File.* |
| WP3 TASK 3.2: Forward modelling of STEREO/HI CMEs (TASK LEAD: UGOE)  The HI-COR2 event list established in WP2 contains 109 events. Out of these, 96 have been modelled with the GCS-method. Self-similar expanding modelling of the CMEs was performed with the GCS-method to determine directional propagation velocities and source region positions and also to derive estimates of their total masses. The data analysis methods were developed in collaboration with the STEREO/SECCHI PI institution at the Naval Research Laboratory, Washington, DC, USA (A. Vourlidas, R. Howard, A Thernisien, N. Savani). The results will be made available through an online database catalogue under development. Results for a sample CME event are shown in Figure 3.4.      Fig. 3.4 Sample mass and velocity determination for a CME observed on 19 April 2010. Forward Modelling fits are shown superimposed on the STEREO-A and B COR images (top). |
| WP3 TASK 3.3: Inverse modelling of STEREO/HI CMEs (TASK LEAD: UGOE)  UGOE has established an “Inverse Modelling List“ (Figure 3.5), based on inspection of STEREO coronagraph and EUV data, which has been used by TCD to provide a “Low Coronal Event Catalogue“ available online at http://grian.phy.tcd.ie/helcats/ (Figure 3.6), aimed at establishing structure and activity in the solar atmosphere associated with the CMEs listed. It contains information on CME source region magnetic field configurations and various activity parameters, such as EUV wave properties and Alfvén speeds.    *Fig. 3.5 Prototype “Inverse Modelling List”.*    *Fig. 3.6 Prototype “Low Coronal Event Catalogue”.* |
| WP3 TASK 3.4: Comparison of modelling results (TASK LEAD: UGOE)  The results of the COR2 CME speed determinations derived under WP3 task 3.2 are being compared with the speeds derived with the HI results derived from geometrical modelling under WP3 task 3.1. Furthermore the determined COR2 CME source region positions will be compared with the positions derived from HI modelling. This is on-going work that will mature as the cataloguing and kinematic fit activities progress. |
| WP3 SUMMARY/NEXT STEPS:  In the next steps we will establish access to the online COR2 database providing speed and mass results to which further processed additional events from WP 2.3 will be added. The results from the COR2-HI comparisons will be analysed statistically. TCD will analyse the photospheric magnetic field properties of the identified CME source regions and coronal activity features such as EUV wave propagation directions and speeds. In terms of deliverables, WP3 has three major deliverables that will be completed at the end of the project (month 36), namely (deliverable D3.2) completing the incorporation of the forward modelling results into the catalogues (although this is an on-going activity), (D3.3) reporting on the model results and (D3.4) reporting on the prototype inverse model activities. However, a major deliverable is D3.1, which is provision of the time-elongation maps and incorporating the fits for the geometrical modelling into the HI CME catalogue (from WP2). This is due month on 12 but would also be updated as events are detected with the on-going STEREO mission. |

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| WORK PACKAGE 4 (WP4):  Verifying the kinematic properties of STEREO/HI CMEs against in-situ CME observations and coronal sources |
| WP4 ACTIVITY TYPE: RTD |
| WP4 DURATION: MONTHS 10 – 36 |
| WP4 LEAD BENEFITIARY: UNIGRAZ (2) |
| WP4 LEADER: Dr Christian Möstl |
| WP4 CONTRIBUTORS: UNIGRAZ (2), UPS (3), UGOE (4), ROB (5), IMPERIAL (6), UH (7) |
| WP4 OVERVIEW: The primary goal of WP4 is to provide researchers with a catalogue which links CMEs observed in the low corona, coronagraphs, and heliospheric images with their *in situ* counterparts. To this end, individual lists of CMEs and their parameters in the low corona (EUV), coronagraphs, heliospheric imaging (HI) and in situ data are underway of being established, covering the timeframe April 2007 to December 2015. Most of these data and lists are now available, as summarized in this report. Windows in time and space for which associations between different phenomena in different datasets will be established in the upcoming months, such that the lists can be linked – forming the linked catalogue “LINKCAT“. A first release of LINKCAT on the HELCATS/products website is scheduled for M24 (April 2016). LINKCAT will provide the basis for many investigations on CME physics and kinematics, of which the first examples are shown here. A summary of the progress in each of the tasks is given below. |
| WP4 TASK 4.1: Comparing to coronal sources (TASK LEAD: UGOE)  Spatial and temporal windows, which are needed for relating HI and COR2 CME observations to low coronal events such as flares will be defined once the first preliminary LINKCAT will be established (see also Task 4.3 below) in the upcoming months.  A list of low coronal signatures (which we call LOWCAT) will be taken from the current UGOE catalogue (available until 2011):  <http://www.affects-fp7.eu/cme-database/database.php>  Links for CMEs in COR2 to HI are available at another UGOE catalogue (WP2/3) (so far until 2011):  <http://www.affects-fp7.eu/helcats-database/database.php> |
| WP4 TASK 4.2: Comparing to in-situ measurements (TASK LEAD: UH)  The goal of the Task 4.2 is to construct a comprehensive catalogue of ICMEs measured *in situ* and to list their key parameters and the results of modeling based on *in situ* data. Since the annual report, the in situ data (DATACAT) and ICME catalogues (ICMECAT) have been revised. As stated in the work plan, all data shall be made available until end of 2015. Thus, the following datasets will be updated during this WP until all data are available, which is expected to happen until mid 2016. Before this, the catalogues will be internally released between all project partners, and then publicly released once fully completed.  Summary of currently available data and lists  DATACAT: the catalogue of in situ data contains plasma and magnetic fields at various spacecraft, starting with January 2007. We summarize what is currently available for each spacecraft as stated in the work plan.  UNIGRAZ (C. Möstl, P. Boakes):  For Venus Express (VEX), the available data of magnetic fields (VSO coordinates) covers 1 January 2007 to the end of the mission on 25 November 2014, thus it is considered as complete. Two datasets are available, one with all data and one with an exclusion of intervals that VEX spent inside the Venus bow shock, based on a general model that does not include bow shock modifications during CME impacts. Both datasets have a time resolution of 1-minute and the IDL .sav file for each version has 263 MB.  For MESSENGER at Mercury, with magnetic fields in MSO coordinates, there are also 2 datasets available, one with and the other without the Mercury magnetosphere, covering Mercury flybys in January 2008, October 2008, October 2009, and including continuous data after Mercury orbit insertion on 18 March 2011, currently up to 18 March 2014. The data have 1-minute time resolution, and each IDL .sav file so far has 101 MB. The mission ended on April 30 2015, thus about 1 year of data at Mercury is still left for processing, and about 4 years during the cruise phase (in RTN coordinates).  Ulysses: Plasma and magnetic field data at 1-hour resolution have been processed for 1 January 2007 - July 2009, when the mission ended, thus our dataset is complete. Useful for HELCATS is the last pass of Ulysses through the ecliptic in August 2007.  UH (A. Isavnin, E. K. J. Kilpua):  The following data all have magnetic fields in HEEQ coordinates and plasma data available (speed, density, temperature):  STEREO-A data are available from 1 January 2007 to 31 Aug 2014. Due to the conjunction of STEREO there is a complete data gap 20 March - 9 July 2015. Thus the data need to be updated until the end of 2015 when available.  STEREO-B data are available from 1 January 2007 until 31 August 2014, which is only month 1 away before loss of contact to the spacecraft on 27 September 2014, thus the data are almost complete.  Wind data from the L1 point in the near Earth solar wind are available from 1 January 2007 – 31 December 2014. These data will also be updated until the end of 2015.  ICMECAT  ICMECAT will include clear ICME events, which satisfies the two criteria of elevated total field strength compared the background wind and the presence of a magnetic obstacle, which contains a smooth magnetic field, either rotating (which defines a magnetic flux rope, MFR) or with constant direction, or a complex ejecta. Due to the different data availability of VEX and MESSENGER, which deliver magnetic fields, whereas Wind and STEREO data contains magnetic field and plasma parameters, the criteria for the lists at each spacecraft are slightly different. How much this introduces a bias will be assessed with the studies on the HI to in situ connections in WP 4.3, and the ICMECAT will be adapted if necessary (e.g. clean the STEREO ICME lists for events that do not contain magnetic obstacles).  The lists from various sources for each spacecraft have been further brought into normalized time formats as described extensively in the annual report. A paper on the VEX / MESSENGER Catalogue by S. Good et al. (2015) has been submitted to Solar Physics. The following table provides an overview of the event numbers and timeranges we have so far:     |  |  |  |  |  | | --- | --- | --- | --- | --- | | Spacecraft | Provider | Number of ICMEs | Start time | End time | | Wind | T. Nieves-Chinchilla | 135 | Jan 2007 | Dec 2013 | | STEREO-A | L. Jian | 167 | Jan 2007 | Jun 2014 | | STEREO-B | L. Jian | 133 | Jan 2007 | Dec 2013 | | VEX | S. Good | 81 | Jan 2007 | Dec 2013 | | MESSENGER | S. Good  R. Winslow | 33  61 | Jan 2007  May 2011 | May 2012  Sep 2014 |   Specific updates since the first annual report:  - the new list by Winslow et al. (2015) has been added which consists of 61 ICMEs observed at Mercury after orbit insertion, with 10 events overlapping between the Winslow and Good lists, thus 84 unique ICMEs observed by MESSENGER remain.  - a shock list was provided by V. Krupar (IMPERIAL) for Wind. From Jan 2007 to Jul 2015, the list contains shock times, shock angles and before / after magnetic field and solar wind speed for 383 events.  - another shock database also available at UH <http://ipshocks.fi> Both are very useful for comparison to WP3 results if no ICME is present.  - A collaboration has been started by UNIGRAZ with the University of New Hampshire (R. Winslow, N. Lugaz, C. J. Farrugia) to identify spacecraft lineups, i.e. ICMEs that have been subsequently detected at the different spacecraft, relevant for understanding the interplanetary CME evolution.  In summary, 435 ICMEs were observed close to 1 AU (Wind, STEREO-A, STEREO-B), plus 165 events in the inner heliosphere by VEX and MESSENGER. This number contains only events after January 2007 so they overlap with the HI catalogue from WP2/3. In total, 600 events are currently in the ICMECAT. Once the full data are available until end of 2015, this number can be expected to rise to approximately 650 events. |
| WP4 TASK 4.3 Assessing the validity of the HI modelling (TASK LEAD: UNIGRAZ)  In this task we will validate the modeling methods used in WP3 to extract CME parameters from HI with multipoint *in situ* data. Since the annual report progress has been made on CME case studies using the preliminary HICAT and ICMECATs:  Source position vs. CME propagation direction:  The paper Möstl et al. (2015, Nat. Comm.) has been published about a major false alarm for a CME on January 7 2014. A synthesis of data from 7 spacecraft (as used in this WP) has shown that a CME may erupt in a direction that is about 40° different in heliospheric longitude compared to the position of the source region. A follow up paper by Mays et al. (2015, ApJ, in press) has further confirmed this with ensemble numerical simulations, and showed that the 3D orientation of the CME was also favourable in missing the Earth, even though the CME source on the Sun was perfectly aimed towards us.  Multipoint studies of ICMEs with spacecraft lineups:  Figure 1 shows an example of an ICME detection that is contained in ICMECAT, taken from Good et al. (2015, ApJ). A triple lineup of a CME flux rope observation has been studied, from MESSENGER to VEX to STEREO-B, in November 2011. Few such radial observations of MFRs have been previously reported, and they shed direct evidence on the evolution of CMEs from the Sun to Earth. The results confirmed previous results on CME flux rope expansion, but showed that the magnetic flux was conserved between 0.44 and 1.09 AU, suggesting that the rope underwent no significant erosion through magnetic reconnection between MESSENGER and STEREO-B. Derived from force-free fits, the rope axis rotated by 30° between the spacecraft to lie closer to the solar equatorial plane at STEREO-B. Such a rotation, if it is a common feature of coronal mass ejection propagation, would have important implications for space weather forecasting.  Ongoing studies:  Establishing the links from the observations of CMEs unambiguously from Sun to Earth is a largely unsolved problem in heliophysics. However, it is crucial e.g. for case studies concerning MFR production on the Sun, which may make possible to give accurate predictions of the internal magnetic field, and hence geoeffectivity, of CMEs. This is extremely important for space weather forecasting because CME MFR orientations can affect dramatically their ability to drive geomagnetic disturbances. With the combined catalogues from HELCATS, this problem can be solved.  In-situ magnetic structures compared to magnetic field of their photospheric source regions  An example for how we tackle this problem is shown in Figure 2. A flare and CME erupted on April 11 2013 and has impacted the Earth on April 14 2013. The movies we have produced with the preliminary catalogue (screenshots in panel c, contained in the previous annual report) allow a straightforward connection of the solar to the in situ data. This event will be further studied with P. Vemareddy (Indian Institute of Astrophysics). The event features a very clear example of a rotation of the EUV wave, and its flux rope can be modeled with reconstruction methods. (CME id: HCME\_A\_\_20130411\_01 and HCME\_B\_\_20130411\_01)  Interaction of CMEs  A study on an event on June 5-7 2011 seems of high interest concerning the interaction of 2 CMEs, with a lineup of MESSENGER, VEX, STEREO-A.  Direct comparison of GCS results to in situ data  ROB: The COR2/Graduate Cylindrical Shell modeling results from WP3 will be compared to the detections in the ICMECAT, to identify the predictive capability of the GCS model. |
| WP4 SUMMARY/NEXT STEPS:  4.1: The lists from UGOE on low coronal signatures will be used to establish events that are connected from the lowcorona (LOWCAT catalogue) to the HICAT, ARRCAT, and ICMECAT. See Figure 4.2 for an example for such a complete connection.  4.2: - UNIGRAZ will look at MAVEN solar wind plasma and magnetic field data once they are released starting with beginning of November 2015, and process to normalized formats if suitable.  - UNIGRAZ and IMPERIAL: Magnetic field cruise data with RTN coordinates for MESSENGER for 2007-2011 will be processed. Update MESSENGER data at Mercury (MSO and RTN).  - IMPERIAL and UNIGRAZ: Append events from the Winslow et al. (2015) MESSENGER catalogue to the Good et al. (2015, submitted) catalogue. Add “ICME\_start\_time“ to VEX and MESSENGER catalogue from Simon Good (currently contains “magnetic obstacle“ start and end times). Update VEX ICME catalogue until the end of mission.  - UH updates L1 Wind data to end of 2015, STEREO-B to September 27 2014, and STEREO-A as available.  - UH starts to determine ICME parameters from the ICMECAT and DATACAT.  4.3: - UNIGRAZ: learn on association time and space windows for connecting events in the low corona, COR2, HI and in situ. Start with ICMEs at Earth, include shock lists, then proceed to include other planets and spacecraft. Based on these results, the first LINKCAT will be established, based on the LOWCAT, HICAT, ARRCAT, and ICMECAT, which is a deliverable until M24 (April 2016).  - ROB: directly compare GCS results from WP3 (UGOE) to ICMECAT (similar to Rodriguez et al. 2011) |

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| WORK PACKAGE 5 (WP5):  PRODUCING A DEFINITIVE CATALOGUE OF CIRs IMAGED BY STEREO/HI THAT INCLUES VERIFIED MODEL-DERIVED KINEMATIC PROPERTIES |
| WP5 ACTIVITY TYPE: UPS |
| WP5 DURATION: MONTHS 1 – 36 |
| WP5 LEAD BENEFITIARY: STFC (1) |
| WP5 LEADER: Dr Alexis Rouillard |
| WP5 CONTRIBUTORS: UH (7) |
| WP5 OVERVIEW: The primary goal of WP5 is to provide a catalogue of the spatial and temporal evolution of Stream Interaction Regions (SIRs) (and their substructures) observed by HI in 3-D, following their complete formation process using different observations (mainly imaging but also in-situ) from the Sun out to 1 AU. The output of the solar wind stream advanced catalogue will be optimized to help the space physics community in the search for clues on the origin, propagation, 3D morphology, and the planetary effects of CIRs and the slow solar wind. |
| WP5 Task 5.1: CATALOGUING THE OCCURRENCE OF CIRs (TASK LEAD: UPS)   * Using J-maps and optimized running-difference images, we will list the times of observations of each CIR in HI images [Done] * From the CIR fitted trajectories, we will provide a catalogue of the arrival times of CIRs at Mercury, Venus, Mars, Earth, Saturn, thereby providing support to European-funded space missions around these planets [Done A]. |
| WP5 Task 5.2: DERIVING/CATALOGUING THE KINETIC VARIATION OF CIRs (TASK LEAD: UPS)  We will fit the leading edge of each CIR in HI J-maps derived at all available latitudes to obtain the spatial/temporal evolution of each CIR over ~180o longitude [Done for STEREO-A] and ~90o latitude [In process]  WP5 Task 5.3: COMPARING BACK-PROJECTED CIR TRACKS WITH CORONAL SOURCES (TASK LEAD: UPS)   * Using the derived trajectories and kinematic properties of CIRs and their small-scale transients, we will determine for each CIR observed in white-light images if there is an associated coronal hole observed in EUV [Done for STEREO-A].   WP5 Task 5.4: COMPARING FORWARD-PROJECTED CIR TRACKS WITH IN-SITU MEASUREMENTS (TASK LEAD: UPS)   * We will track small-scale transients to 1 AU and make a list of predicted impacts at points in the heliosphere where in-situ measurements are taken [Done for STEREO-A, ACE, WIND and STEREO-B].   More detailed summary for Task 5.1, Task 5.2, Task 5.3 and Task 5.4:  Using J-maps derived from running-difference images, Illya Plotnikov (recruited in May 2014) has listed the times of passage of each Corotating Density Structures (CDS) in the field of view of HI images obtained from STEREO-A (Goal 1 in T5.1). We then used our technique to determine the location of each CDS in the ecliptic plane as a function of time. In order to determine the time-dependent evolution of the 3-D trajectory of each SIR, the characteristic tracks left by these SIRs in the J-maps were fitted manually by clicking on J-maps produced with HI-1 and HI-2 images from STEREO-A (and in the future STEREO-B). For each SIR, we fitted first the clearest tracks associated with individual density irregularities entrained by the SIR. We then used the fact that a SIR corotates during its passage in the heliospheric imagers, thereby leaving a characteristic pattern in the J-map. This pattern was then computed theoretically and superposed onto the real J-map. The algorithm to trace this SIR pattern folds in a correction for the orbital motion of the spacecraft. This orbital motion changes the location of the viewpoint of the probe (STEREO-A) and can have an important effect when the SIR pattern is considered over a 180o of corotation in the HI field of view lasting up to 18 days. To validate a fitting we use two criteria (1) we require that the correspondence between the simulated and measured SIR patterns are satisfactory, (2) we require that the fitting technique (‘fixed-point technique’) of the trajectory of individual small-scale transients entrained by the SIR gives small errors in both speed (<40 km/s) and direction (<20o). Both of these criteria usually impose that the SIR be well observed by the heliospheric imagers over a large range of elongations (>40 degrees). CDSs that are poorly observed because (1) the white-light signature is too weak, (2) too many CMEs passed in the field of view are not fitted.  Once a SIR is fitted, we assign it a time that corresponds to the launch time of the small-scale transient entrained by the SIR that is best observed during the event. We adopted this definition of the onset time because it guarantees that if a future user wishes to find this SIR in the heliospheric imagers, the single feature will be most easily spotted as a bright signature in the images (especially with the ‘propagation tool’: c.f. WP8 for more details). The Carrington longitude and latitude of the source region of the SIR was also recorded and was systemically compared with EUV images. For each event, we recorded whether a coronal hole was present less than 20o of longitudinal separation to the East of the SIR source region and recorded its location in Carrington coordinates (Goals 1 and 2 of T5.3). The format of the catalogue is given in the first annual report  WP5 SUMMARY/NEXT STEPS:  Since the annual report, Illya Plotnikov has completed the entire catalogue of CDSs from STEREO-A (2007-May 2014). He has compared the catalogue with various sets of in-situ measurements taken by STEREO-A, ACE/Wind and STEREO-B at the predicted times of impact of the CDS. The comparison shows that the fitted CDSs have speeds close to the slow solar wind speed and not the speed of the stream interface measured in situ. He has also demonstrated that CDSs are mostly S/CIRs and that all S/CIRs are detected by HI during the solar minimum period but at solar maximum the large number of CMEs passing in the field of view prevents the identification of half of the passing S/CIRs. He has also demonstrated that CDSs occur mostly at sector boundaries in situ and at the neutral line at the Sun and therefore the close relation between CDSs and small transients expelled in the palsma sheet. All these findings are included in a paper that will be soon submitted :  Plotnikov, I., Rouillard, A.P., Davies, J.A., Long-term tracking of corotating density structures using heliospheric imaging, to be submitted to Solar Physics, 2015.  Illya has also investigated the possibility of fitting CDS in STEREO-B heliospheric images, however this is very difficult because the pattern left by the passage of CDSs in STEREO-B images is less clear. He has therefore developped a new scheme that is based on the STEREO-A fitting. He predicts the pattern of CDSs from STEREO-A to STEREO-B by letting the structure corotate in HI1-/2B, if the pattern generated in STEREO-B is reproduced, then a CDS is validated in that field of view. So we are deriving a new CDS catalogue for STEREO-B based on the STEREO-A catalogue.  Upcoming updates: Illya is now investigating the effect of spacecraft motion which was recently demonstrated by Conlon et al (2015) to affect fitted speeds by a few tens of km/s. An updated CDS catalogue will be produced including spacecraft motion. Future deliverables (Due month 24) include the fitting of the leading edge of CIRs and determination of their latitudinal extend.  Eduardo Sanchez-Diaz (recruited in Nov. 2014); has investigated the speed of small transients in HI and has found that they have very slow speeds, that these small-scale transients retain very slow speeds up to 0.3-0.4AU and investigated whether HELIOS-measured such low speeds in solar cycle 22. These speeds are indeed measured in situ up to 0.6 AU, this provided additional confidence that our speed calculations are correct. A paper was submitted to Geophysical Research Letters but after a mitigated referee report mainly due to suitability of the paper for the GRL format, we decided to re-submit to JGR. Eduardo has identified times when blobs emitted from the corona observed in STEREO-A images are propagating towards STEREO-B and L1, he is currently analysing this data.  We note two papers related with the HELCATS work in this WP:  Sanchez-Diaz, E., Segura, K., Rouillard, A.P., Lavraud, B., Chihiro T., The very slow solar wind: origin, variability and properties, to be submitted to JGR, 2015.  Plotnikov, I., Rouillard, A.P., Pinto, R., Using heliospheric imaging to predict the arrival time of CIRs at various points in the inner heliosphere, to be submitted shortly to Solar Physics, 2015 |

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| WORK PACKAGE 6 (WP6):  INITIALISING ADVANCED NUMERICAL MODELS BASED ON THE KINETIC PROPERTIES OF STEREO/HI CMEs AND CIRs |
| WP6 ACTIVITY TYPE: UPS |
| WP6 DURATION: MONTHS 7 – 36 |
| WP6 LEAD BENEFITIARY: UPS (1) |
| WP6 LEADER: Dr Alexis Rouillard |
| WP6 CONTRUBUTORS: GMU (Third-party) |
| WP6 OVERVIEW: The primary goal of WP6 is to transform the catalogues of CMEs and CIRs observed by HI, accomplished in WP2/3 and WP5, into more advanced catalogues of simulations results of CIRs and CMEs. This advanced database will provide to the space community a set of simulation results optimised by assimilating direct images of the solar wind into ENLIL simulations. The delivery of these advanced catalogues will enhance forefront research on the ‘background’ solar wind (fast and slow solar wind) and on the spatial and temporal evolution of CIRs and CME shocks, and will provide unique material to study and interpret particle radiation measurements in the inner heliosphere. |
| We have addressed a subset of the goals of the four tasks defined for WP5, namely:  T6.1 - Assimilating HI images to model the background solar wind [Months: 7-36]  UPS  The combination of the catalogues of CIRs derived in WP5.1 and WP5.2, J-maps derived from HI images and movies has been compared with preliminary synthetic J-maps of CIRs derived from numerical simulations of the background solar wind (ENLIL) through the propagation tool. We are currently dividing events in two classes: Class 1 for which a good correspondence is immediately obtained between simulated and observed height-time maps and Class 2 for which J-maps differ significantly. Since the annual report, Rui Pinto has modified his potential field source surface code to take different magnetograms (Wilcox Solar Observatory, Mount Wilson and Solar Dynamics Observatory). Has has also pursued the numerical effort to run his solar wind model to produce Carrington Maps of solar wind parameters at 21.5Rs to initialise ENLIL. He is now validating his model with in situ data. We have started comparing the catalogue of Corotating Density Structures (S/CIRs) from WP5 with our PFSS reconstructions based on Wilcox Solar Observatory data.  T6.2 - Assessing the use of HI to initialize ENLIL [Months: 7-36] UPS  Since the annual report, we have read the catalogues produced by WP3 to locate CMEs relative to CIRs/SIRs by projecting their trajectories on the source surface. We are also comparing the 3-D trajectory of CME derived from WP3 with the trajectory of CMEs located by the NOAA alert system and available through synthetic J-maps derived by the ENLIL model. We are also evaluating the latitudinal extent that will have to be considered for the injection of CMEs in the MHD model. The synthetic J-maps are produced by computing the white-light heliospheric images that STEREO-A and STEREO-B should see from their vantage points. These images are derived by applying the equations of Thomson scattering from the simulated 3-D volume of electronic densities. The code computes running-difference images and like ordinary J-maps, a band of pixels is extracted along the ecliptic plane. These J-maps have so far been produced for 2012 and 2013. We integrated them in our software tool and can switch from these maps to real J-maps. In the tool, we can now superpose the catalogue of J-maps derived in WP5. This allows us to compare the trajectories and patterns left by CIRs derived from observations with the trajectories of CIRs derived from numerical simulations.  T6.3 - Continual assimilation of HI data in ENLIL and comparison with standard implementation techniques [Months: 7-36]  We will start this task in Month 24.  Papers in preparation:  Pinto, R., Rouillard, A.P., Wang, Y.-M., Grappin, R. The acceleration of the solar wind along magnetic flux tubes of varying geometries, to be submitted to Astrophys. J., 2015.  Rouillard, A.P., Plotnikov, I., R. Pinto,… ,The expansion of coronal pressure waves in 3-D during Coronal Mass Ejections, to be submitted to Astrophysical Journal, 2015. |

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| 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 CONTRIBUTORS: STFC (1); ROB (5) |
| WP7 OVERVIEW: The main goal of HELCATS WP 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 both by 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 both by 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, has considerable prior experience in the analysis of radio data). Regarding Task 7.1 the 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 established the foundations of the approach to cataloguing the data, 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). Note, since IPS data are not uniformly available (the radio-telescope systems used here run on a campaign basis only for observations of IPS) 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 analysis programme enables all of the available data to be analysed using an automated mode that finds the CME events. This is in progress. Planning is underway for how to best address the SIR aspects of Task 7.1 (using ideas and approaches based on those used in Bisi et al., Solar Physics, 2010).   With a data catalogue now coming online, work is 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. 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 being performed. 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, Oct. 2015.   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 more closely examine 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 that 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 Nov. – 1 Dec. 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 such 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 available at multiple points. 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 very good overall 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., 2015, *in prep.*). 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 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 to 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 that 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. 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 UGOE <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 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 underway. 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 the height-time analysis for a CME observed between 29 Nov. – 1 Dec. 2013 (Krupar et al., 2015, in prep.). 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:  7.1: It is expected that good progress will be made towards a complete and consistent analysed data set of the available EISCAT/ESR and LOFAR IPS data throughout the STEREO mission period. 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. The work to complete the catalogue is on-going. 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. |

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| WORK PACKAGE 8 (WP8):  DISSEMINATION |
| WP8 ACTIVITY TYPE: OTH |
| WP8 DURATION: MONTHS 1 – 36 |
| WP8 LEAD BENEFITIARY: STFC (1) |
| WP8 LEADER: Dr Chris Perry |
| WP8 CONTRUBUTORS: UPS (3), IRAP |
| WP8 OVERVIEW: WP8 oversees the logistics of the dissemination of data and information to the project, the Commission and the wider community, with the website as the principal tool ([www.helcats-fp7.eu](http://www.helcats-fp7.eu)). Although the website is formally the responsibility of WP1, the posting of information through material posted on the website, including the basic format and information on the website, posted documentation, links etc… is the job of WP8 and this has been done, to allow efficient running of the project and the distribution of information as required. This includes the project (private) wiki page. Meeting minutes and reports are posted as required. WP8 also oversees documentation standards and formatting, including the catalogue structure. Information distributed outside the webpage such as press releases are also managed through WP8. Dissemination is also concerned with the running of the HELCATS meetings such as the six monthly project meeting in ROB in November 2014 and the Annual Workshop and project meeting in UGOE in May 2015. The WP also includes the ingestion of products into the AMDA data-mining IRAP (UPS) propagation tool, and integration with projects such as HELIO. This WP coordinates the exploitation of the project outputs, such that they feed into numerous research activities and future space weather applications. |
| WP8 TASK 8.1- PUBLICATION OF RESULTS AND CONCLUSIONS (TASK LEAD: STFC)  This WP Task focuses on the publication of documents relevant to the project, including posting on the website. In the reporting period, this includes meeting reports and minutes, teleconference minutes, the catalogues that are being constructed as the project progresses. We also note that some scientific papers are in preparation and will be submitted soon, and some papers have indeed appeared in the professional literature (see WP reports above).  IRAP contribution:   * The work carried out by the IRAP is leading to four papers that have and will be submitted over the next two months. One on the presence of a very slow solar wind (1st author: submitted by Eudardo Sanchez-Diaz), one paper on the statistical properties of CIRs tracked in HI and their relation with in-situ measurements (1st author to be submitted by Illya Plotnikov), one paper on the influence of magnetic field line topology in the low corona on the terminal speed of the solar wind (1st author not yet submitted by Rui Pinto), one paper on the extent of coronal shock waves observed in white-light images (1st author not yet submitted by Alexis Rouillard). |
| WP8 TASK 8.2 – ANNUAL OPEN MEETINGS WITH THE SCIENCE COMMUNITY AND PRESENTATION AT MAJOR SCIENCE MEETINGS (TASK LEAD: STFC)  This report coincides with the first Annual Open Workshop of HELCATS, where the HELCATS community and the wider scientifc community will engage in scientific discussion on project-related science. The Open Workshop will include key presentations from the HELCATS team and from the community (see the details on the website) and is a major tool for advertising HELCATS progress and activities. A full programme of talks has been scheduled and a healthy attendance from within the project and beyond guarantees that this will be major event for heliospheric physics.  Whilst a number of preject-related publications are listed in the WP descriptions above, some HELCATS participants have presented HELCATS results at major meetings, e.g. Eduardo Sanchez-Diaz has presented his results on the very slow solar wind at EGU in April 2015, and Rui Pinto showed the results of work on solar wind acceleration at the AIC meeting in Tampa, Florida in April 2015.  IRAP contribution:   * Eduardo Sanchez-Diaz has presented his results on the very slow solar wind at EGU in April 2015 and at the L ‘Aquila summer school in September 2015. * Rui Pinto showed the results of work on solar wind acceleration at the AIC meeting in Tampa, Florida in April 2015 and as an invited talk at the Solar Wind 14 meeting in Weihai. Alexis Rouillard presented his work in an invited talk at the IUGG in Prague and the 1st Solar Orbiter/Solar Probe+ meeting in Florence. |
| WP8 TASK 8.3 – INSTALLATION OF RELEVANT DOCUMENTS, CATALOGUES, PUBLICATIONS ON THE PROJECT WEBSITE (TASK LEAD: STFC)  The website has been actively utilised from the start of the HELCATS project with basic information, but also with posted meeting information, documents, reports and minutes of meetings and teleconferences. This includes the catalogues themselves. Most of the site is public, but there is a private project area where some telecon minutes are lodged. |
| WP8 TASK 8.4 - INTEGRATE WITH RELEVANT, ESTABLISHED COMMUNITY FACILITIES AND WEBSITES (TASK LEAD: STFC)  The WP descriptions, above, have discussed the progress of the catalogues as they develop, and this includes the use and links to existing catalogues and websites for comparisons. The comparison of HI and coronagraph CME catalogues is a case in point, as is the integration of the catalogue facilities at RAL (STFC) with the UK Solar System Data Centre. Another facility that is key to the HELCATS work, for WP5 and 6, is the AMDA facility at UPS. The ENLIL work is also linking to an established MHD model and we have integrated ENLIL simulations to the propagationtool.cdpp.eu so that the community can also have access to the synthetic J-maps. Thus, the project has many ‘integration’ activities in progress and we refer the reader to the relevant WP sections.  IRAP contribution:   * The IRAP catalogues are being produced in both .xml format (VOtables) and .ascii readable by most computing languages. * The CIR catalogue developed in WP5 has been integrated in the ‘propagation tool’ (propagationtool.cdpp.eu). This has required some modification of the tool that was supervised by Alexis Rouillard. We are currently integrating the CME catalogue produce by WP2 for both the fixed point and the harmonic mean techniques. This should be operational in the coming weeks. The next step will be to create a webservice between our tools and the source archive of all these catalogues at STFC. * We have also integrated ENLIL simulations to the propagationtool.cdpp.eu so that the community can also have access to these synthetic J-maps. * The CME catalogues produced in WP3 with the fixed phi and harmonic mean techniques have been integrated in the propagationtool.cdpp.eu and this is used in WP6. |
| WP8 TASK 8.5 – DISSEMINATION OF INFORMATION TO THE PUBLIC AND POLICY MAKERS (TASK LEAD: STFC)  The website is openly available to the public with information about the project and access to most of the project documentation and activities. The website includes news items, events, tweets and information on meetings. There is much background information for the non-professional, interested reader. The HELCATS team members are very active in ‘live’ space projects (e.g. STEREO, Cluster, Hinode) and in the increasing space weather activities, such as ESA’s Space Situational Awareness (SSA) space weather programme. The HELCATS project has been widely discussed, especially in space weather fora, because it is seen as pioneering and spearheading the assessment of HI observations along with associated data and modelling methods in a way that can have a major influence on future space weather strategic applications. Many members of the Steering Committee, including the Coordinator and the Scientific and technical Manager, are actively involved in SSA projects. In the UK this has involved close involvement with the Met Office, which is now an established space weather forecasting facility for the UK Government. |
| WP8 SUMMARY/NEXT STEPS:  The WP8 descriptions, above, are clearly defining an on-going process in terms of the varying aspects of dissemination. The activities, as described will continue throughout the project. The basic activities that are described relate to deliverables D8.1 to D8.8, all of which run through the entire project and are formally ‘delivered’ by month 36. |

# Summary

The WP reports, above, describe a multifaceted project with clear aims and a focus on transients in the heliosphere. As planned, at the end of the first 18 months, there are numerous elements to the work underway with clear paths to bringing aspects together as the project progresses. In terms of the project deliverables HELCATS is on track and we are seeing impressive results in bringing together a unique set of catalogues and the assessment of a range of key methods. Thus, the project is functioning well and we anticipate, already, a solid legacy for the future.

The WP descriptions provide specific summaries and pointers to the future but we bring out one point here, that is mentioned in the WP8 summary. The growth of the ESA Space Situational Awareness space weather programme is something that has taken place in parallel with the conception of HELCATS through to its implementation. It is abundantly clear that HELCATS is a thoroughly unique, global assessment of the added value of HI observations, of related data and of modelling methods, and the results will undoubtedly be fundamental to the application of HI observations in any future HI programme within a European space weather programme.

Having said that, the careful coordination of HI and associated data with the key modelling codes means that the project is well set to provide a truly unprecedented view of the heliosphere for the scientific community.