DEPARTMENT 4: Solar Physics

SECTIONS 8 & 9: Structure and Dynamics of the Solar Atmosphere & Solar Activity

Introduction: overall objectives and evolution of the Department

The year 2005 has been a very exciting year for the Department of Solar Physics. The year started with a renewal of our PRODEX projects (now PRODEX8), most of them for a period of two years (2005-2006), some of them for three years. The Solar Physics Department of the ROB thus continues to flourish, supplementing the limited Observatory dotation with a significant amount of external funding from peer-reviewed competitive tenders. At the end of 2005, the SIDC harbored 15 researchers and 6 project experts. The technical staff consisted of 5 people, including since January 1st 2005. Mr. A. Ergen. Two new contractual post-doc scientists were welcomed in the team, these are: Dr. I. Baumann and Dr. L. Rodriguez. The in-house science staff was supplemented by long-term visitors Dr. V. Slemzin, Dr. C. Marque, Mrs. J. Patoul and Mrs. K. Verheyen.

Up to 20 original science papers were published (+8 papers that are either in press or accepted for publication) during the year in internationally refereed journals. The self-imposed OPPY target (one paper per person per year) was thus successfully met in 2005 and we are close to 2 papers per active researcher. This has been an especially strong result taking into account that a lot of time & energy has not been available for publishing. Indeed, the permanent services (see below), the preparation of the SECCHI mission (launch 2006) and the PI-participation in SWAP and LYRA onboard PROBA2 (launch 2007) are requiring significant resources. New participations in future space mission after 2007 were actively searched for. Dr. J.-F. Hochedez became co-investigator on PREMOS (onboard CNES mission PICARD, launch 2008), Dr. D. Berghmans became co-investigator on AIA (onboard NASA mission SDO, launch 2008) as representative of the ROB.

In May 2005, Dr. R. Van der linden -up till then acting department head- was nominated Director General of the Royal Observatory. After he left, Dr. D. Berghmans took up duty as acting department head of the Solar Physic Group. Dr. F. Clette remained in charge of the sub-team managing the ground-based instruments (see below). With only 2 senior scientists in permanent positions left within the group, a signficant fraction of the project management was delegated to scientists in contractual positions. Dr. A. Zhukov (lead STEREO project) and especially Dr. J.-F. Hochedez (lead LYRA and EIT projects, work leader since April 2005) bring a much appreciated contribution in this respect.

Important changes also occurred in the ground-instrumentation. The solar physics activities at the radio-astronomy station in Humain were halted on July 31, 2006. Since then, the site and the remaining personnel came under direct control of the Director General. In many annual reports preceding the current one, it was pointed out that manpower was lacking to maintain both the Humain radio-astronomy station as well as the Uccle Solar Equatorial Table. At the same time, attempts to attract additional resources for the radio-astronomy station were not given a fair chance. Therefore the decision was finally taken to concentrate all manpower on the USET instruments and to abandon -at least temporary- radioastronomy in Humain while hoping for better times for radio solar physics in the future.

This drastic action has made it possible to concentrate the technical efforts on the USET instruments. Mr. J-L. Dufond and Mr. A. Ergen are now working as Lead and Assistant Instrument Technicians on the development, maintenance and operations of the USET instrument under the guidance of Dr. F. Clette. They are assisted by a contractual operator (Mr. O. Boulvin, Lead Observer) for the daily observations. Still the lack of technical staff remains problematic. One calculator position became vacant after a 2-year

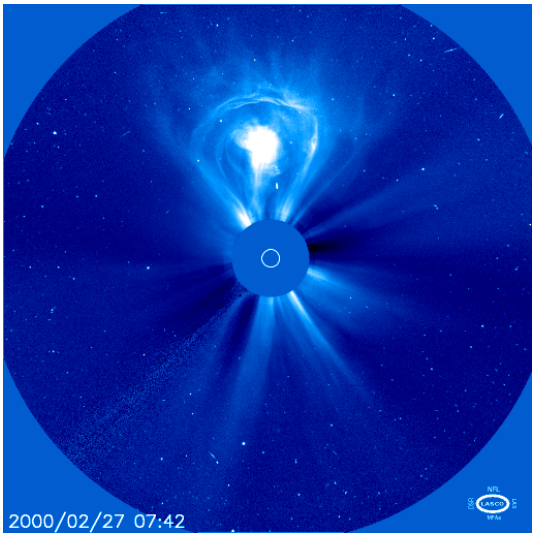
procedure in May 2005 (D.Carré, permanent invalidity). The procedure to have this position filled has been running since then and is now within the hands of SELOR. Two more retirements are foreseen in the coming year, putting the activities of the World Data Center for the Sunspot Index under serious pressure. Already now can the SIDC as World Data Center for the sunspot index only survive thanks to the support of USET technical staff, post-docs and even the Director General. More stable manpower for the WDC is highly needed.

Despite this problematic situation, the daily operations of the SIDC -as a center for *scientific servicing* to the community- have been again an absolute success. Besides the production of solar observations from the USET telescopes (246 drawings and 1900 CCD images), the SIDC produced among others 365 daily ursigrams, 52 weekly bulletins, 12 Monthly Ri Reports, 12 Monthly Ri_hemispheric Reports and 79 presto alerts.

In order to remove the confusion that seems to exist over the relationship between the SIDC and the Solar Physics Department of the Royal Observatory of Belgium, it was decided to identify the name 'SIDC' with the entire scope of activities of the Solar Physics Department. In the remainder of this chapter, the term "SIDC" and the "Solar Physics Department" will be used in parallel and refer both to the full solar physics team at ROB, active in fundamental research as well as in scientific servicing. This report was edited by D. Berghmans on the basis of contributions by F. Clette, J.-F. Hochedez, R. Van der Linden and A. Zhukov.

A. CME Studies

Coronal Mass Ejections (CMEs) are probably the most spectacular phenomena observed on the Sun. A CME is a huge bubble of plasma threaded with magnetic field lines that is ejected from the Sun over the course of several hours. The Large Angle and Spectrometric Coronagraph (LASCO) on the Solar and Heliospheric Observatory (SOHO) is the first instrument that has detected CMEs routinely over a timescale comparable with a solar cycle. At solar minimum we observe about one CME a week. Near solar maximum we observe an average of 2 to 3 CMEs per day.

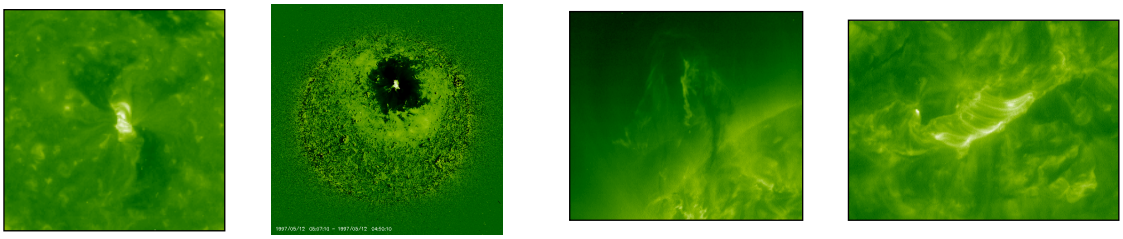


The study of CMEs is important for solar-terrestrial relations as some CMEs may be directed towards the Earth and – with a suitable magnetic field orientation – produce geomagnetic storms. They are therefore seen as the solar events causing the most hazardous space weather conditions on earth. They can trigger geomagnetic storms which e.g. affect the terrestrial communication and the reliability of power systems. (see Research Theme "Space Weather").

CMEs are mainly observed as intensity enhancements in coronagraphic white light images. However, the *origin* of CMEs cannot be traced by coronagraphs, as the occulting disc obscures a direct view of the initiation site. The Extreme-ultraviolet Imaging Telescope (EIT) onboard the Solar and Heliospheric Observatory (SOHO) with its full disc coverage is well suited for the detection of CME initiation in the solar atmosphere.

Figure 1: The "lightbulb" Coronal Mass Ejection (CME) showing the three classical parts of a CME: leading edge, void, and core. (SOHO/LASCO)

Studies have shown that a number of phenomena observed with EIT are indeed precursors to the CMEs seen by coronagraphs. These phenomena include dimmings, EIT waves, prominence eruptions and flares. None of these associated phenomena are however a necessary condition for the occurrence of a CME. Different CMEs can be generated or associated with a variable subset of this list. The observations made by EIT are used to obtain information about the still-enigmatic CME initiation mechanisms.



Dimming EIT wave Erupting prominence Post-eruption arcade

Figure 2: Different on-disc signatures of CMEs observed by EIT onboard SOHO.

At the ROB, we are interested in the understanding the complete CME process from its precursors on the solar disc, down to its effect on the Earth magnetosphere. This research theme thus naturally touches at the "Space Weather" research theme (see below) but is in contrast to the latter – which is of an applied nature – concerned with fundamental research. More specifically our fundamental questions are:

- *understanding the CME initiation process.* We want to understand which structures and events are precursors for CMEs. Based on the characteristics of the eruption source, can we determine the later evolution of the CME?
- *understanding the internal structure of CMEs*. What is the structure of an interplanetary CME? What is its 3D magnetic configuration? How can it be deduced from the observations?
- *understanding the geo-effectiveness of a CME.* What determines the ability of a CME to trigger a geomagnetic storm? Can we simulate this process? Can we estimate the time-of-arrival of a CME at the magnetosphere?

The ROB heritage as co-investigators in the LASCO & EIT instruments has given us good understanding and access to the state of the art instrumentation (see the 'Coronal heating' research theme for details on our EIT activities). The most important upcoming space mission for CME studies is the STEREO twin spacecrafts mission, with each spacecraft carrying the SECCHI remote sensing instrument package. The ROB is again co-investigator for this mission. We actively prepare the exploitation of this mission on the basis of LASCO/EIT images.

The ROB is also principal investigator in the PROBA2 mission. PROBA2 is an ESA technology demonstration mission that is scheduled for launch in September 2007. Besides the demonstration of state-of-the-art technology, PROBA2 has also a scientific payload consisting of the Lyman alpha radiometer (LYRA, see "Solar Irradiance" research theme) and the Sun Watcher using APS and image processing (SWAP). SWAP in an evolved version of EIT, especially optimized for observations of CMEs on the solar disc.

Finally, the ROB also participates in a Belgian network ("Solar Drivers of Space Weather") for numerical simulations of CMEs. The network consists of the Von Karman institute (contributing advanced numerical methods), the KULeuven/CPA (project lead and contributing expertise in MHD simulations), BISA (contributing magnetospheric know-how) and ROB. The role of ROB is to provide observational input that can be used as initial conditions for the simulations. ROB has contributed for this the CACTus software (Computer Aided CME Tracking).

In what follows, we will give a detailed overview of our activities in the 'STEREO/SECCHI' project, the 'SWAP' project and the 'Solar Drivers of Space Weather' project. All three projects are supported by ESA/PRODEX and specifically aim at studying coronal mass ejections.

A.1. STEREO/SECCHI

A.1.1. Objectives

STEREO is a NASA space mission consisting of two identical spacecraft that will observe the solar corona and heliosphere simultaneously from 2 viewpoints in the ecliptic plane. In Belgium, both the ROB and the 'Centre Spatial de Liège' (CSL) are co-investigators in the consortium that builds the SECCHI instrument suite for the STEREO spacecraft. The role of the solar physics group of the ROB is the scientific preparation of this mission. The primary goal of SECCHI (Sun Earth Connection Coronal and Heliospheric Investigation) is to advance the understanding of the 3D structure of the solar corona, especially regarding the origin of coronal mass ejections (CMEs), their evolution in the interplanetary medium, and the dynamic coupling between CMEs and the Earth environment.

A.1.2. Progress and results

The launch of the STEREO spacecraft is for July 2006. Once the commissioning phase ends and both spacecraft are inserted in their heliocentric orbit, the nominal mission will begin. The routine scientific data flow will probably start only in the first half of 2007. In the current pre-launch phase the SECCHI team at the ROB concentrates on 1) the development of software tools for SECCHI data processing; 2) CME studies on the base of EIT and LASCO images combined with in situ data.

Development of software tools

Four software tools for the automatic processing of the SECCHI data on the ground are currently being developed: the Solar Weather Browser, CACTus, EIT wave/dimming detector and Velociraptor.

The *Solar Weather Browser* is a visualization interface that was originally developed for the "SIDC ESA Space Weather Applications Pilot Project". It aims to provide the solar physics community with a powerful tool to access large amount of solar observations in a fast and efficient way. During 2005 the data from several new instruments (LASCO, SPIRIT, Catania Halpha, etc) have been successfully added. A number of bugs in the server part of the software has been fixed and some important features have been added (for example the ability to process data from different dates). Those changes resulted in a much more reliable and useful software, better positioned to serve the needs of the solar physics community.

The *Computer Aided CME Tracking* (CACTus) software has been further developed. It is designed to automatically detect coronal mass ejections (CMEs) in coronagraphic images from LASCO onboard SOHO. The detection of a CME is done in two steps and is applied simultaneously on C2 and C3 running difference images: (1) detection of bright features moving radially outward (2) clustering detections into CMEs. CACTus is the first of its kind (Robbrecht & Berghmans, 2004, A&A) and serves now as reference for other CME detection software which is currently being developed elsewhere. During 2005 the software has been continuously maintained, running in real-time. CACTus real-time performance has been evaluated monthly, focusing on the email-alerts which it sends out (whenever a CME larger than a critical threshold is detected an email is sent to registered users). During 2005 38 correct halo CME alerts and 7 false alerts have been sent. We could fix most problems responsible for false alerting. A possible implementation of the wavelet "A trous" algorithm to enhance the contrast (without taking running differences) has been investigated. Although it turned out to be possible to use wavelet instead of running difference, the new algorithm has not been implemented. The background in the LASCO images has been studied. It contains the F-corona and streamers. Both have to be removed from the images if not using the

running difference technique. The noise in the LASCO images has been studied and the cleaning routine has been adapted.

Using CACTus, objective CME catalog has been created by March 2005, spanning the LASCO archive. The current output covers data from 1997 – 2004 and is available online. CACTus will be used to analyse the images from the two pairs of STEREO coronagraphs, first with the beacon data and subsequently with the science data. CACTus catalogues will be an integral part of the SECCHI real-time space weather monitoring effort and the results of every CACTus scan will be made available via the WWW as soon as they are available. To facilitate this, the ROB STEREO team agreed to install the current real-time version of CACTus on the local machine at the Naval Research Laboratory (NRL, SECCHI PI team) running initially on real-time data from the LASCO coronagraphs onboard SOHO but also on simulated data from two simultaneous viewpoint as will be provided by SECCHI. The installation of CACTus on the designated NRL computer will be fully operational there by Feb 2007.

The version of CACTus compatible with the SolarSoftWare (SSW) was developed and tested during 2005. Initially this version worked interactively after a user provided a set of dates for analysis; toward the end of 2005 work began on the process of developing a version of SSW-CACTus which would run in real time in batch mode, automatically scanning the real-time archive for recently-arrived images and processing them. The real-time variant of SSW-CACTus is expected to be running routinely at ROB by early 2006. The output will be monitored alongside the existing CACTus output to check for consistency and agreement, and SSW-CACTus will eventually become the default version. The transition is anticipated by mid 2006.

Additionally, its incorporation into the SECCHI analysis suite means that CACTus' input requirements will have partly shaped the nature of the SECCHI beacon mode. The CACTus performance on beacon data has been investigated as a test for SECCHI. Beacon data are highly compressed low resolution COR-2 data (covering the field of view of 2 to 15 solar radii) and will be used for space weather forecasting. The smaller field of view (in comparison to LASCO) only can cause problems for the detection of fast CMEs (faster than 1000 km/s). Since these are the most important for space weather, enough images (ideally 8 per hour) have to be acquired in the beacon mode. The lower resolution of the beacon data will influence the accuracy of the detection and the detection of very small events, but this is no problem for space weather forecasting. Efforts by the ROB STEREO team continue to ensure the optimal combination of images for CACTus' operation.

The *EIT wave and dimming detector* aims at detecting the occurrence of Earth-directed CMEs in their earliest stages as EIT waves and coronal dimmings in the EUV observations of the solar disc. The software is written in MATLAB 7 and is now in the stage of being set up. Event occurrence is detected using high order moments in base difference images. The appearance of such coherent structures as EIT waves and dimmings increases strongly the mathematical moments (variance, skewness, and kurtosis) of the spatial intensity distribution. These high order moments are zero for the normal Gaussian distribution for pure white noise that one would expect if the Sun is quiet. They can thus be used for the detection of occurrence of organized large-scale structures. The next step is to determine the location, timing, structure and dynamics of the EIT wave and the associated dimming. Final validation deals with dimming area verification. Fast increase of dimming area is found to be a robust statistically established criterion of EIT wave presence on the Sun.

Velociraptor is based on a new image-processing tool that will simultaneously estimate both motion and intensity variation from two successive EUV coronal images. It is an application of a method developed in the research theme "*The Variable Magnetic Corona"*.

In addition to the post-acquisition data processing tools, a method of 8-bit *data recoding* that will be used by the SWAP imager on PROBA2 (see Nicula et al. 2005) was presented to the SECCHI consortium. The flexibility of the method was demonstrated to the officials responsible for SECCHI onboard image processing and compression. Following extended and detailed discussions during the first half of 2005 it was agreed that the 8-bit recoding method would be included from the very beginning as part of the onboard compression options for the SECCHI instrument package. The results of the application of the method to data capturing a variety of solar events – CMEs, flares, EIT waves, dimmings – were presented. It was demonstrated that all these important signatures of solar activity were readily observed in 8-bit data and thus space weather monitoring and studies were not hindered by the reduction in bit-depth. The results of the method as applied to coronagraph data had been presented for the first time; previously the method had only been used with full-disk images of direct (as opposed to scattered) solar radiation.

In order to *display* the observations provided by SECCHI in a stereoscopic frame, special hardware and software are required. Software must perform an offset perspective projection for each eye, thus simulating what each eye would see if it were immersed in the three-dimensional virtual world that the software renderings are based on. The necessary hardware includes a workstation with a graphics card capable of providing a sync signal (to differentiate the views) and stereoscopic visualization eyewear. Currently, neither the software nor the hardware is available at ROB. Starting in late 2005, the different possibilities in order to obtain a full implementation to produce stereo images are being evaluated.

CME studies on the basis of EIT and LASCO images

A key objective of the STEREO mission is the phenomenon of Coronal Mass Ejections (CMEs). The CME initiation process in the low corona will be observed in the extreme-ultraviolet (EUV) by SECCHI, and its data can now be simulated with the SOHO/EIT data.

An important factor for CME studies is the pre-eruption configuration of the coronal magnetic field. It is well-known that most of the CMEs originate from inside the streamer belt of the solar corona. A study of the three-dimensional structure of the streamer belt has been performed, in collaboration with the Laboratoire d'Astrophysique de Marseille (LAM). A model developed at LAM permits to simulate the quasi-stationary configuration of the streamer belt starting from the National Solar Observatory photospheric magnetograms and using the potential field source surface model. The synoptic maps of the streamer belt obtained with SOHO/LASCO C2 coronagraph and the simulated synoptic maps constructed from the model of the warped plasma sheet have been compared. The earlier findings have been confirmed: the streamers are associated with folds in the plasma sheet. Although the large-scale structure of the streamer belt is described reasonably well, some features, however, cannot be explained in this framework. It has been proposed that two types of large-scale structures take part in the formation of these additional features. The first one is an additional fold of the neutral line, which does not appear in the modeled source surface neutral line, but is well visible in photospheric magnetograms. The second one is a plasma sheet with a ramification in the form of a secondary short plasma sheet. It was shown that if these structures are taken into account, the observed configurations of the streamer belt can be better described. The secondary plasma sheet can be formed between two secondary current sheets connected with the main current sheet. The result suggests that the potential field source surface model is not fully adequate for the description of the fine structure of the streamer belt, even during the epoch of low solar activity.

The investigation of the streamer belt configuration during the epoch of high solar activity was started. The position of the current sheet can be found comparing the position of streamers, of loops observed by EIT and of neutral lines at the photosphere or chromosphere. Instead of the photospheric neutral line, the chromospheric neutral lines traced by filaments have been used as its configuration is smoother. To determine the position of the chromospheric neutral lines more precisely, the chromospheric synoptic maps have been acquired from P. McIntosh (HELIOSynoptics).The method turned out to work surprisingly well for the main large-scale structures associated with the polar crown filaments. The reason is that

streamers during the activity maximum are more radial, as can be seen during total solar eclipses (collaboration with S. Koutchmy, Institut d'Astrophysique de Paris). Again, the streamer belt may have a configuration different from the one given by the potential field source surface model. The folds of the current sheet correspond well to the folds of the chromospheric neutral line.

An investigation of low corona counterparts of flux rope CMEs have started. It turns out that the symmetric double dimming structure is not always observed. Moreover, in some cases the dimming pattern covers a large part of the solar disc. This indicates a non-local character of the CME initiation process. Possible reasons of such a behavior are currently under investigation.

An EIT wave triggering an EUV flare has been found. By performing the timing-location inter-flare analysis, a statistically significant flare-to-flare remote triggering for whole ensemble of solar flares (with EUV, Halpha, hard X-Ray data of solar disk) has been found. Detailed studies of this issue show that perturbations created by an initial flare, propagate at characteristic velocities around 110 km/s and can trigger a distant flare when encountering remote marginally stable pre-flare magnetic structures, resulting sometimes in series of events.

A study of the CMEs connection with their interplanetary counterparts has been started. The study of CMEs in the interplanetary medium (ICMEs) is normally hampered by the fact that the in-situ data used represents only a 1D cut through a full 3D structure. To increase the amount of information available, one has to use data from several spacecraft. Currently these are ACE, Ulysses and SOHO, in the near future STEREO data will be available. Multi-spacecraft studies are best suited to help unveil open questions regarding the internal structure of CMEs. When the source region is clearly discernable, EUV and white light data can be used in order to correlate characteristics seen during eruption with those measured in-situ. A flux rope model can be applied to those ICMEs which present a cloud structure, using data from the different satellites, in order to get a better approximation of what the global structure of magnetic clouds may look like. The techniques developed under the present project will be used for the investigation of STEREO data. Results from these studies will be combined with those obtained in the frame of the working group "The Stages of Sun-Earth Connection", one of the groups forming the "International Teams Program" supported by ISSI (Bern, Switzerland). In collaboration with Sergio Dasso (IAFE, Argentina) a study has been started in order to correlate different signatures with the boundaries of ICMEs, of special interest is to define whether the limits of an ICME as seen in magnetic field data correlate to the boundaries dictated by composition data.

A.1.3. Perspective for next years

The development of the software products will be continued. The clustering technique of CACTus will be improved. A new version of the online CME catalog, covering data from 1997 – 2005, will be created using the updated software. The SSW versions of CACTus and EIT wave/dimming detector will be finalized and tuned so that they are compatible with the SECCHI data and can be run on the data of each spacecraft separately. The conversion to SSW-CACTus will be followed by the widespread distribution of the routines via the SSW network and its implementation by other institutions. Monitoring the real-time installation of SSW-CACTus at NRL working with LASCO and simulated multi-point data will continue. This latter study will lead to a fully operational version for the dual-spacecraft SECCHI environment prior to STEREO launch.

EIT wave detection technique can be greatly improved. New criteria will be developed with the new SECCHI data of better resolution and time cadence. An online EIT wave catalog will be created, covering data from 1997 – 2005. The nature of triggering agents of sympathetic events will be investigated. LASCO images for the Solar Weather Browser will be enhanced by adopting the 8-bit recoding method

already utilized for solar disk images. This will de-noise the images and make the files smaller, reducing demands on server storage, bandwidth, and user cache size

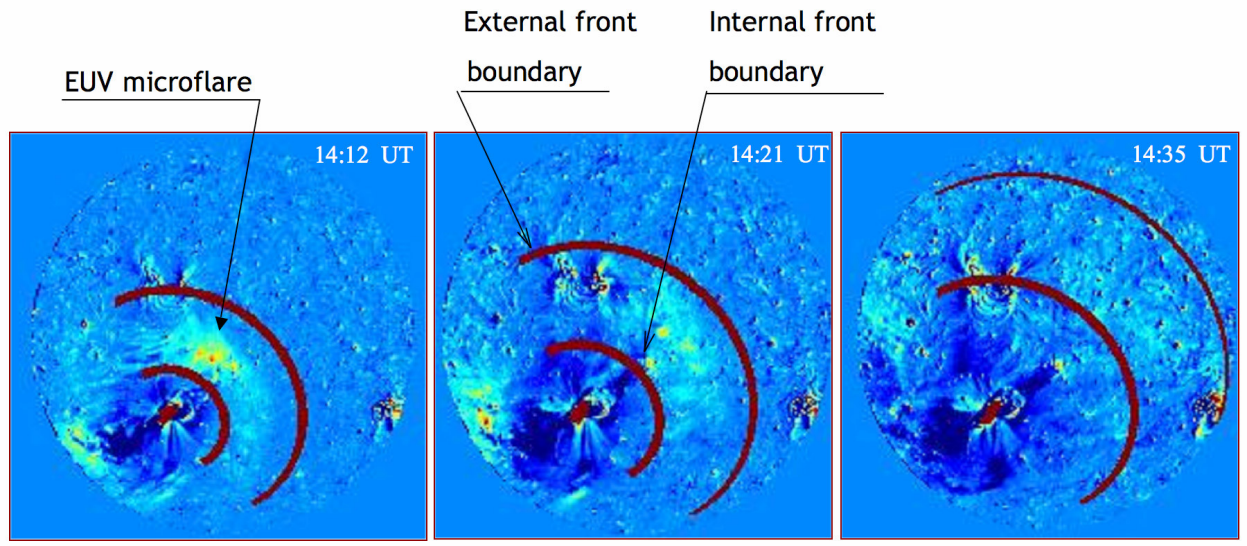


Figure 3: Detection of EIT wave of April 7, 1997

The investigation of the streamer belt will be continued. The model will be applied to several Carrington rotations during the epoch of high solar activity, taking as input the chromospheric neutral lines. The positions of streamers as observed and as given by the model will be compared. Later the model will be applied to the SECCHI data expected in the end of 2006. The study of low corona and in situ counterparts of CMEs will be continued to get an insight into the 3D structure of CMEs. The necessary tools in order to obtain stereo visualizations will be implemented.

A.1.4. Personnel involved

Project lead: D. Berghmans (A. N. Zhukov since January 2006).
People hired on the project: A. N. Zhukov, E. Robbrecht, E. Podladchikova, L. Rodriguez (since October 1, 2005).
Additional contributions from: G. Lawrence, B. Nicula, S. Gissot, J.-F. Hochedez.

A.1.5. Partnerships

List of national and international partners:

The ROB-SECCHI team is a member of the international SECCHI consortium which is led by the Naval Research Laboratory (NRL, Washington DC). The complete consortium list is:
Naval Research Laboratory, Max-Planck Institut fur Aeronomie, University of Kiel, Rutherford Appleton Laboratory, Mullard Space Science Laboratory, NASA Goddard Space Flight Center, University of Birmingham, Centre de Spatial Liege, Lockheed Martin Advanced Technology Center, Centre d'Astrophysique Spatiale, Institut d'Optique, USAF Space Test Program, Swales Aerospace, Hytec Incorporated, Praxis Incorporated, The Hammers Company, Boston College, Smithsonian Astrophysical Observatory, Royal Observatory of Belgium, Observatoire de Paris, Laboratoire d'Astronomie Spatiale, NASA Jet Propulsion Laboratory, Science Applications International Corporation, Stanford University, University of Michigan, Southwest Research Institute. More information can be found on http://projects.nrl.navy.mil/secchi/organizations.html Collaborations with the Institut d'Astrophysique de Paris (France) and IAFE (Argentina) have also been established.

Grants used for this research:

ESA/PRODEX Contract C90131 "SECCHI Exploitation".
ISSI Grant for International Team "3D Reconstruction Techniques for the Stereo Mission"

Visitors: 5

A.1.6. Publications

A.1.6.1. Publications with peer review

Robbrecht, E. & Berghmans, D.
Entering the era of automated CME recognition: a review of existing tools
Sol. Phys. 228, pp. 239-251 (2005)

Podladchikova, O., Berghmans, D.
Automated detection of EIT waves and dimmings,
Sol. Phys. 228, 267-286 (2005).

Saez, F. **Zhukov, A.N.**, Lamy, P., Llebaria, A.
On the 3-dimensional structure of the streamer belt of the solar corona
Astron. Astrophys. 442, pp. 351-358 (2005).

A.1.6.2. Publications without peer review

Podladchikova, O., Berghmans, D.
Interaction of EIT wave with active regions on the Sun
Solar Wind 11 - SOHO 16 Conference Proceedings*,* ESA SP-592, pp 535-538 (2005).

Podladchikova, O., Berghmans, D.
Energetic dynamics of EIT wave structure analyzed by EIT Wave Detector
Solar Wind 11 - SOHO 16 Conference Proceedings, ESA SP-592, pp.751-754 (2005).

A.1.6.3. Publications in press, submitted

Robbrecht, E. & Berghmans, D.
A broad perspective on automated CME tracking: Towards Higher level Space Weather Forecasting Geophys. Monograph Series, Book title: Solar Eruptions and Energetic Particles, *in press* (2005)

Podladchikov, V.N., Naroditskaya, N., **Podladchikova, O.**
Adaptive filtering in the presence of constraints on estimated parameters
Problems of Informatics & Control, *in press* (2005).

Podladchikova, O., Berghmans, D.
Quantitative study of EIT waves dynamic characteristics. I.Topology and energetics of EIT wave structures
Astron. Astrophys., *submitted* (2005).

Podladchikova, O., Berghmans, D.
Quantitative study of EIT waves dynamic characteristics. II. Structural changes in the solar active regions during the interaction with EIT waves fronts
Astron. Astrophys., *submitted* (2005).

Podladchikova, O., Krasnoselskikh, V., **Berghmans, D.**, Lefebvre, B., Nakariakov, V., **Van der Linden, R.**
Can flares trigger other flares in distant active regions?
APJL, *submitted* (2005).

A.1.6.4. Reports, thesis, etc

Eva Robbrecht's PhD report of work done during academic year 2004-2005
12 Monthly reports summarizing the real-time performance of our automatic CME detection software CACTus

A.1.7. Missions

Research missions (conferences and scientific visits): 19
Operational missions (commissions, working groups, consortium discussions): 6
The SECCHI project does not require field missions (observations, station maintenance).

A.2. PROBA2/SWAP (Sun Watcher using Active Pixel system detector and image processing)

A.2.1. Objectives

SWAP is an extreme ultraviolet (EUV) solar imager launching in 2007 on ESA's PROBA2 technological platform. Using off-axis optics and EUV-enhanced active pixel sensor detector (coated APS) it will image the corona every minute, detecting phenomena (solar flares, EIT-waves) associated with CMEs. On-board and ground-based image processing will automatically detect these phenomena and issue alerts, serving as a high performance solar monitoring tool for operational space weather forecasting.

A.2.2. Progress and results

During 2005 the ROB SWAP team continued to provide scientific and technical expertise and support to the instrument technology institute at the Centre Spatial de Liège (CSL); during the year this primarily concerned the proximity electronics, and detector/focal plane assembly. Several critical issues on the noise levels generated in the electronics have been identified and discussed with CSL. A campaign at CSL (see mission list) highlighted certain key areas as being compromised by a lack of a clear understanding of certain components of this system. The ROB-SWAP team provided constant input to CSL to resolve these issue and by the end of the year it was felt that the system was well understood and that the necessary steps to improve the actual flight systems had been identified, and work was in progress at CSL to implement them. A critical step during the year was the selection and characterization of the flight model detector at PTB Bessy over the course of two campaigns (see mission list). ROB participated fully in both campaigns. From the results of the first campaign it was concluded that the multi-layer coatings on both samples were below the acceptable standard for the flight model. Five further uncoated samples were ordered from FillFactory (Belgium) with the SWAP team assuming responsibility for arranging their coating by AST (UK); two of the five were coated, and were characterized during the second Bessy campaign, leading to the selection of the flight model. The data are still being analyzed and the results will be utilized during the full instrument calibration campaign scheduled immediately prior to instrument delivery in August 2006. The ROB team participated in the SWAP CDR (see mission list), the conclusions of which are partly summarized in several mission documents (see document list).

The onboard software driving the instrument and processing its images is to be developed by Spacebel (Hoeilaert), commencing 2006. Specifications and interpretation support were provided by ROB and CSL to Spacebel (see mission list below), and subsequent consultations regarding modification. A special recoding technique was developed to boost the performance of generic compression techniques (eg JPEG) which will be integral to the onboard software. Initial discussions with the PROBA2 ground segment team (Redu and Spacebel staff) regarding the interface of the SWAP science center, proved constructive. It was agreed to wait for the prime contractor selection for the PICARD CMS ground segment before progressing further, and a meeting was held with the PICARD responsible on December 16. The

SWAP/LYRA science ground segment will be organised as closely in parallel with the PICARD one as possible. The EIT-wave detector and the Solar Weather Browser currently developed within the STEREO project, as well as the flare detector developed within the SIDC RWC project, are earmarked for transitioning to the SWAP project. This activity will kick-off following instrument delivery.

A proposal was submitted (and accepted) for ESA support to the 'PROBA2 Solar Operations' as a Nationally Led Mission, which would transfer post-launch control of PROBA2 from ESA's Technology Directorate to Science. One of the goals of this proposal is to obtain a second ground station, as it is long established that SWAP will suffer from a significant telemetry shortfall particularly since the approval of a modified orbit in 2005. The additional operations require additional manpower resources, which ESA has agreed to support, and ESA SPC has appointed Herman Opgenoorth to open a negotiation phase on how much ESA will contribute. Enquiries as to the availability and suitability of several resources were made by the ROB SWAP team, and also by BELSPO, and a study of the various options will be concluded in mid 2006. Regarding the modified orbit, its ramifications with regard to visible light eclipses and EUV occultations, and energetic particle impacts on overall system degradation and individual image degradation were studied, since there was initially some flexibility over the orbit altitude. The final choice of orbit parameters was made in Sept 2005.

Additionally, PROBA2 will benefit from enhanced international awareness and recognition as a result of adoption as an ESA science mission, and this is augmented by the approval of proposals to include PROBA2 in NASA's 'International Living With a Star' (ILWS) programme, and the International Heliophysical Year (IHY) framework. Also, a proposal was accepted for an international "Science Consortium for SWAP and LYRA' (SCSL) team at ISSI (Bern) in June 2006. The SCSL will assemble a team of international expertise that will assist the ROB PI teams for SWAP and LYRA to optimise the scientific return of the two instruments. This will be the first of several meetings to be held during the pre-launch/operational phase, and will result in a community-based agreement on a data analysis policy and support, amongst numerous areas. Scientific know-how is being accumulated within ROB, by both SWAP team and associated researchers, for the future scientific exploitation of SWAP data, involving literature studies and publication on EIT waves, flare statistics, CME eruptions, etc. PROBA2/SWAP was presented at several conferences (see mission list), and in the literature. In addition, the SWAP website (http://swap.oma.be) was completely re-worked in early 2005, and will be further updated in early 2006; the website has benefited from increased visibility via the ESA, ILWS and IHY connections.

A.2.3. Perspective for following years

The following milestones are foreseen:
- Commence SWAP ground segment work package: early 2006
- Commence writing SWAP instrument paper for pre-launch peer-reviewed publication: early 2006
- Conclude study of potential additional ground station resources, mid 2006
- SWAP& LYRA ISSI meeting: June 18-23, 2006
- SWAP final calibration: beginning of August 2006
- SWAP delivery to PROBA2: Aug 23 2006
- PROBA2 launch: September 2007

A.2.4. Personnel involved

Dr. David Berghmans (ROB SWAP Project Manager); Mr. Bogdan Nicula, Dr. Gareth Lawrence, Dr. Thanassis Katsiyannis are hired on the SWAP PRODEX grant. Important contributions are brought by other personnel of the Department of Solar Physics such as Dr. J-F. Hochedez, Dr. F. Clette and Dr. A. Zhukov.

A.2.5. Partnership

List of national and international partners:

Centre Spatial de Liege, Liege, Belgium
Centre for Plasma Astrophysics, Catholic University, Leuven, Belgium
P.N. Lebedev Institute, Moscow, Russia.
Max Planck Institute, Lindau, Germany.
ESTEC, Noordwijk, NL.

Grants used for this research:

ESA/PRODEX Contract C90193 "SWAP Preparation to Exploitation".

Visitors: *During the course of the year we have welcomed many (>10) visitors in the context of the industrial development (e.g. onboard software) of the SWAP instrument.*

A.2.6. Publications

A.2.6.1. Publications with peer review

Nicula B., Berghmans B., Hochedez J.-F. *Poisson recoding of solar images for enhanced compression,* Sol Phys 2005, 228, 253-264

A.2.6.2. Publications without peer review

Katsiyannis A. C., Berghmans D., Hochedez J.-F., Nicula B., Lawrence G., Defise J.-M., **Ben-Moussa A., Delouille V., Dominique M**., Lecat J.-H., Schmutz W., **Theissen A**., Slemzin V., *SWAP: An EUV imager for solar monitoring on board of PROBA2,* SPIE, 2005, 5901, 236.

Katsiyannis A. C., Berghmans D., Nicula B., Defise J.-M., **Lawrence G**., Lecat J.-H., **Hochedez J.-F**., Slemzin V., *SWAP: An EUV imager for solar monitoring on board of PROBA2,* ESA SP-596, p70

Lawrence G, Berghmans D., Hochedez J.-F., BenMoussa A., Defise J.-M., **Delouille V., Dominique M., Katsiyannis A.,** Lecat J.-H, **B. Nicula B**, Schmutz W, Slemzin V & **Theissen A.,** *Space Weather with ESA's PROBA2 mission,* **ESA SP-592**, p.695, 2005.

A.2.6.3. Publications in press, submitted

Berghmans D., Hochedez J.-F., Defise J.-M., Lecat J.-H., **Nicula B.**, Slemzin V., **G. Lawrence**, **Katsyiannis A.**, **Van der Linden R.**, **Zhukov A.**, **Clette F.**, Rochus P., Mazy E., Thibert T., Nicolosi P., Pelizzo M.-G., Schuhle U. *SWAP onboard PROBA-2, a new EUV imager for solar monitoring,* Adv. in Space Res., 2005, in press, available online April 27, 2005

Katsiyannis A.C., Berghmans D., Nicula B., Defise J.-M., **Lawrence G**., Lecat J.-H., **Hochedez J.-F**., Slemzin V., *SWAP: An EUV imager for solar monitoring on board of PROBA2,* 7th HELLAS, submitted.

A.2.7. Missions

Research Missions: 5
Operational Missions: 1
Field Missions: 10

A.3. Solar Drivers of Space Weather

A.3.1. Objectives

The "Solar Drivers of Space Weather", ESA PRODEX 8 project is a collaboration between the ROB (PI : R. Van der Linden), BISA, VKI and K.U. Leuven. The purpose of this project is to study the physics behind the recurrent structure, heating and acceleration of the solar wind, the acceleration of energetic particles, and the formation and propagation of transients like CMEs and induced shocks from their birth in the solar corona up to their arrival at the Earth's magnetosphere. Also the background solar wind and the embedded interplanetary magnetic field (IMF) are studied as the environment through which the CMEs propagate. The past IMF can be reconstructed on the basis of the geomagnetic *aa* index. It is our aim to reconstruct the historic IMF starting from a flux transport model on the solar surface and extrapolating the so-obtained surface field into the heliosphere using potential field models.

A.3.2. Progress and results

We have finished work package WP1A which was to model the magnetic field near the Sun from magnetograph observations which can be used as magnetic boundary conditions in the global numerical solar wind simulations performed by the MHD group (S. Poedts and C. Jacobs) at the Center for Plasma Astrophysics of the K.U. Leuven. The propagation of the solar wind and CMEs is described by the three-dimensional magnetohydrodynamics (MHD) equations. The initial magnetic field in the simulations has been substituted from a simple dipole field into a more realistic potential field using the potential field source surface model. In the latter the surface magnetic field is extrapolated into the heliosphere assuming that there are no electric currents above the photosphere and that the magnetic field becomes radial at a so-called source surface (typically set at 2.5 solar radii). This source surface field has been derived from Mt. Wilson magnetograms.

In collaboration with M. Schuessler (Max Planck Institute for Solar System Research) simulations of the historic solar surface magnetic field were made on the basis of the RGO sunspot data (available since 1874) and the monthly sunspot number (available since ~1700) using a flux transport model. The corresponding open magnetic flux is extrapolated once using a potential field model and once using a current sheet model. Doing so, we hope to be able to reproduce the historic IMF variation and thus to present a complete model of the solar large-scale magnetic field containing the solar dynamo, the redistribution of magnetic flux and the extrapolation into interplanetary space.

A.3.3. Perspective for following years

In collaboration with CPA, we foresee to build and evaluate real-time solar wind models for operational use. Later on, CME initiation models will be implemented in this near-real time solar wind model. Finally, these combined simulations will need to be integrated and evaluated as an operational CME simulation tool into the Space Weather operations of the RWC Belgium.

A.3.4. Personnel involved

Project Manager: D. Berghmans
People hired on the project: S. Willemns, I. Baumann
Additional contributions by: R. Van der Linden, P. Vanlommel

A.3.5. Partnerships

List of national and international partners:

Centre for Plasma Astrophysics, Catholic University, Leuven, Belgium
Belgian Institute for Space Aeronomy, Brussels, Belgium
Von Karman Institute, Sint Genesius Rode, Belgium

Grants used for this research:

ESA/PRODEX Contract C90204 “Solar Drivers of space weather”.

Visitors: *<5, mostly partners within the Belgian network*

A.3.6. Publications

A.3.6.1. Publications with peer review

Baumann, I., Schmitt, D., Schüssler, M. A necessary extension of the surface flux transport model Astronomy & Astrophysics, vol. 446, pp.307-314 (2006)

A.3.6.2. Publications without peer review

A.3.6.3. Publications in press, submitted

Cadez V.M., **Vanlommel P.**
Effects of localized horizontal flow patters on eigenfrequencies of stellar global modes
Serb. Astron. J., 171, pp 19-28 (2005).

A.3.7. Missions

Research missions: 1
Operational missions: 1

B. The variable magnetic Corona

The magnetic solar atmosphere is variable at all time-scales. Its faster and smaller phenomena are not resolved with the current telescopes. It is a research topic of the Solar Physics Department (alias SIDC) to bridge observation and theory and addressing at this angle the coronal heating issue. These studies are developed in the first section of the present theme. While Coronal Mass Ejections are treated as a separate theme, flares are considered in the second section dealing with the preparation of the LYRA radiometer. Finally, the last section covers the coronal variability commensurable with the solar rotation or slower.
The solar corona is a very dynamic environment and several mechanisms compete in its various areas. Magnetic energy dissipation can be due to wave dissipation ‘AC’ (if $t_A >> t_p$) or to continuous currents ‘DC’ (if $t_A << t_p$), where t_A is the characteristic transit time of Alfven waves in the loop, and t_p is the characteristic time of sub-photospheric convection. However, to explain heating by Alfven wave dissipation, these Alfven waves must be excited on a time scale shorter than the typical timescale of the corona (t_A~100s), and for example, the characteristic time of granular convection is 400-900s, i.e. too slow. By contrast to the AC mechanisms, the heating theories based on current dissipation operate even with slow

driving. The energy source is then in the random agitation of the footpoints of magnetic field lines and current dissipation produces the heating. The characteristic time of resistive magnetic diffusion is $t\eta = l^2/\eta$, larger than observable scales. Normal resistivity is therefore not an efficient dissipation means. Reconnection is a much faster and more efficient processes with $\sim t_A = l/V_A$. It is the natural candidate to explain phenomena like flares, CMEs, bright points, blinkers, nanoflares observed in closed magnetic field regions. Observational studies associate nanoflares and small-scale reconnections. Constant changes in the magnetic fields dominating the corona lead to many types of instabilities in the coronal plasma and in the magnetic field itself. These instabilities manifest themselves in a variety of scales and events.

EIT will often be referred to in the following. The instrument and the role of its data are therefore briefly introduced here. EIT is the Extreme ultraviolet Imaging Telescope of the Solar Heliospheric Observatory (SoHO). It is monitoring the topology and dynamics of the solar corona and transition region in four different wavelength passbands, which correspond to temperature regimes from 60,000K up to 2,000,000K. The EIT instrument has been built by a Belgian-French-US consortium, and is operated very successfully since January 1996. In November 1998, a PRODEX Experiment arrangement was agreed between the ROB and the European Space Agency (ESA). Since then, its Co-Investigators at the ROB have undertaken numerous studies. Three fields of expertise have been selected for the EIT Science at ROB. One is the analysis of small or rapid phenomena; the second is the development of image processing tools treating automatically and systematically the observations; and the third relates EIT data to Space Weather forecasting treated as another theme.

B.1. Coronal heating

B.1.1. Objectives

All coronal heating theories entail small scales, i.e. large gradients and fast phenomena. While the scales at work are far below current observations, the path to understanding coronal physics involves nevertheless addressing intermediate scales, say one order of magnitude below current observations. Therefore, analysis of existing data is conducted in parallel with participations to the design of future missions, in particular Solar Orbiter, truly capable of a breakthrough in related knowledge.

B.1.2. Progress and results

The activity can be into five parts.

1/ HiC et NUNC (**H**igh **C**adence to study the **N**anoscale **U**ltraviolet **N**etwork and **C**orona) was submitted as an Action 3, and which was granted during 2005. It aimed at studying transient phenomena in the solar atmosphere using the EIT Shutterless data and multi-instrument observations such as CDS, SUMER, MDI and TRACE observations.

2/ The Supplementary Researcher grant (attributed to Dr Parenti) investigates the matching of theoretical magnetic loop models and observations. The idea is to define and study benchmark tests by confronting the small scale observables with the plasma response predicted by theoretical forward models. EIT, CDS and SUMER data will be used to prepare the analysis of upcoming observations by Stereo and Solar-B, and to eventually help define the S.O. payload.

3/ Fractal analysis that aims at characterizing precisely the Quiet Sun and at synthesizing its texture. We have studied the statistical properties of Quiet Sun images using the multifractal spectrum, and we have synthesized images having the same multifractal spectrum as EUV solar images. Such synthesis is additionally useful for calibrating the optical flow technique (Velociraptor/Movatrac) which is developped by Samuel Gissot and Jean-Francois Hochedez.

4/ The EUI-S.O. proto-consortium has met three times (Germany, France, Belgium). Note that the last event happened at the ROB, organized by Jean-Francois Hochedez (JFH). The design and the work breakdown between partners have become more precise in 2005. JFH contributed to the consortium inputs to the various PDD versions (Feb), the mass justification and breakdown issues (Feb and April). He and Armin Theissen created a Wiki interface for the EUI documents (eui.oma.be). During the year, a lot of lobbying effort toward ESA was necessary to defend the mission itself. It involved writing letters to the agencies and lately instigating a second S.O. workshop (Athens 2006, JFH is member of the Scientific Organizing Committee). SIDC and CSL have adopted a strategy foe EUI, which puts emphasis on the FSI.

5/ Organization of a "SOHO workshop". Belspo approved the organization of a large "SOHO workshop". The preparation of this event, anticipated in the Fall of 2007, started in 2005. The first focus has been the definition and the search of an appropriate location.

6/ A project was submitted (and meanwhile accepted) to the 'Ministerie van de Vlaamse Gemeenschap, Departement Onderwijs' in response to the 'Tournesol call 2006-2007'.The title of the project is "Schokgolven en veranderlijkheid van de UV-straling in de corona van de zon" (PI: Thierry Dudok de Wit - Univ. Orleans) and foresees travel money for several joint meetings with research groups in Orleans and Meudon.

B.1.3. Perspective for following years

The shutterless data need to be exploited before new observations surpass them. I will naturally participate to the two investigations mentioned above addressing the Quiet and the Active Sun heating. Finally, the development of the Solar Orbiter seems confirmed but vulnerable at the time this report is written. The future investment of the SIDC in it will have to depend on political decision at ESA level. In 2006, the SOC and most other elements of SOHO20 will be defined. The Tournesol project will lead to a strengthening of the collaboration with the French partners.

B.1.4. Personnel involved

J.F. Hochedez, D. Berghmans, V. Delouille, S. Gissot, M. Madjarska, O. Podladchikova A. Theissen, A.C. Katsiyannis.

B.1.5. Partnerships

List of national and international partners:

IAS, France
CPA, K.U.Leuven
Observatoire de Paris, Meudon
University of Orleans

Grants used for this research:

ESA/PRODEX Contract C90205 "SIDC Data Exploitation".
ESA/PRODEX Contract C90209 "LYRA preparation to Exploitation".
BELSPO Action 3 : Hic et Nunc
Supplementary researcher

Visitors: 8

B.1.6. Publications

B.1.6.1. Publications with peer review

I. Ugarte-Urra, J.G. Doyle, R.W. Walsh, **M.S. Madjarska**,
Electron density and filling factor along a coronal loop observed with CDS/SoHO,
Astron. Astrophys. 439, 351-359 (2005).

J.G. Doyle, J. Giannikakis, L.D. Xia, **M.S. Madjarska**,
Line broadening of EUV lines across the solar limb: A spicule contribution?,
Astron. Astrophys. 431L, 17 (2005).

A. De Groof, C. Bastiaensen, D. Muller, **D. Berghmans**, S. Poedts
Detailed comparison of downflows seen both in EIT 30.4nm and Big Bear H alpha movies
Astron Astrophys, 2005, 443 (1), 319-328

Katsiyannis A. C., Murtagh F., Keenan F.P., *The application of a Trous filtering and Monte Carlo analysis on SECIS 2001 solar eclipse observations,* SoPh, 2005, 228, pp323.

McAteer, J. M. A., Gallagher P. T., Brown D. S., Bloomfield D. S., Moore R., Williams D.R., Mathioudakis M., **Katsiyannis A. C.,** Keenan F. P., *Observations of Ha Intensity Oscillations on a Flare Ribbon,* ApJ, 2005, 620, pp1101.

B.1.6.2. Publications without peer review

Hochedez, Lawrence, Nicula
Belgian contribution to the EUI of Solar Orbiter (presentation by JFH)
1st EUI consortium meeting, Frankfurt

Madjarska, M.S., Doyle, J.G., **Hochedez, J.-F. & Theissen, A.**
Spicules and blinkers as seen in Shutterless EIT 304 A
Proc. on "Chromospheric and Coronal magnetic Fields", ESA SP-596, p. 73

B.1.6.3. Publications in press, submitted

Madjarska, M.S., Doyle, J.G., **Hochedez, J.-F.& Theissen, A.,**
Macrospicules and blinkers as seen in EIT Shutterless 304,
2006, Astron & Astrophys, accepted

D. Garcia-Alvarez, C.M. Johns-Krull, J.G. Doyle, I. Ugarte-Urra, **M.S. Madjarska**, C.J. Butler,
Optical and EUV observations of solar flare kernels,
accepted to be published in Astron. Astrophys. (2005).

Reports, thesis, etc

Hochedez and Madjarska
HiC et NUNC II
Action 3 proposal (failed)

Hochedez and Parenti
Supplementary Researcher proposal (succeeded)

Hochedez, Robbrecht, Berghmans, Lafont
Minutes of the 1st LOC meeting of 19 Sep 05, SOHO 20 preparation

Hochedez, Robbrecht, Berghmans, Lafont

Minutes of the 2nd LOC meeting of 17&18 Nov 05

SOHO 20 preparation

B.1.7. Missions

Operational missions: 3

B.2. UV irradiance and the PROBA2-LYRA radiometer

B.2.1. Objectives

LYRA is a solar XUV to VUV radiometer that will embark in 2007 on PROBA2. Its objective is to monitor the solar irradiance in 4 passbands relevant to Solar Physics, Space Weather, and Aeronomy. LYRA also demonstrates the interest of new solar-blind diamond detectors and the degradation properties of UV filters. It is built by a Belgian–Swiss–German consortium with additional international collaborations (Japan, USA, Russia, France). JFH (ROB) is LYRA's Principal Investigator, Y. Stockman (CSL) is Project Manager, and Werner Schmutz (PMOD) is Instrument Scientist. In 2005, an opportunity to embark LYRA "PIN" detectors on the PREMOS-PICARD mission has emerged (and materialised in '06).

B.2.2. Progress and results

The following up of the LYRA project was carried out by JFH (PI), including participation to all meetings and teleconferences. A PROBA2 Science Management Plan was written jointly with the SWAP project. An ISSI proposal (SCSL) for the scientific exploitation and its international extension was submitted and selected. The SCSL contract was with ESA and ISSI was finished in December.

To materialize the opportunity of flying LYRA PIN detectors on PICARD-PREMOS, an Agreement was prepared between B and CH that is now signed by all parties. It foresees that 3 new PINs will be bought by ROB and PMOD to IMOMEC. It includes also an agreement about data rights. As a consequence of this agreement, JFH became PICARD coI.

A meeting with Dr. Koizumi in Japan was organized to discuss how one can extend PIN sensitivity into the EUV. Dr Koizumi is performing critical steps of the diamond PIN fabrication.

As to MSM detectors, there have been several important concerns in 2005 and earlier in the project that I reported into a thorough open letter to PRODEX. It resulted in a change of the LYRA manager at IMO and a decision to try and reprocess new MSMs on old substrates. This action has taken a lot of effort. It involved designing a new mask concept and writing a traceability memorandum. Nonetheless, LYRA must still carry AXUV (Si) detectors, which is a deficiency in a sense but it does present advantages such as direct real-world comparison of competing technologies.

A LYRA radiometric model was developed by Dr Theissen and Dr Benmoussa under the guidance of Dr. Hochedez. This tool is useful to understand and predict the LYRA signal. It had to be made more complex in order to account for AXUV detectors and various filter possibilities. All project documents maintained in the LYRA document archive have been reviewed with a particular attention to the test and calibration reports written by Dr Benmousa and German colleagues. Calibration plans have been written for all synchrotron campaigns.

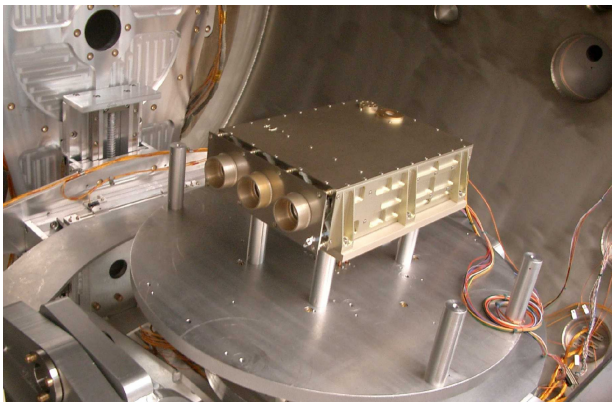


Figure 4: LYRA inside the vacuum chamber of the GI beamline (1-30nm): 11-22 July 2005.

Transmission tests of filters were performed by Dr Benmoussa and Ms Dominique of ROB and 2 colleagues of BISA at RMI and BISA. After heliostat LYRA testing in Davos, it appeared that the Zr and the Ly-alpha Si channels might sense much more contamination than foreseen. The diagnostic was discussed in length and recovery actions implemented.

Ms Dominique is in charge of the LYRA software (specifications and now follow-up). One interesting issue among others has been the pulsation of the LEDs. The future LYRA ground segment has been addressed.

Under the guidance of JFH, preparatory LYRA scientific exploitation was conducted by Dr Delouille (Denoising and flare extraction), Dr Theissen (spectral "inversion", flat field deconvolution 10/5) and Ms Dominique (Aeronomy).

B.2.3. Perspective for following years

The following milestones are foreseen:
- LYRA final calibration: March '06
- LYRA delivery to PROBA2: Spring '06
- Science Consortium for SWAP and LYRA (SCSL) ISSI meeting: June 18-23, 2006 and December 2006
- PROBA2 launch: September 2007

B.2.4. Personnel involved

J.F. Hochedez, A. Ben Moussa, M. Dominique, V. Delouille, A. Theissen, D. Berghmans, B. Nicula, A. Zhukov, G. Lawrence, L. Wauters, R. Van der Linden.

B.2.5. Partnerships

List of national and international partners:

Centre Spatial de Liège, B
IMO/IMOMEC, Diepenbeek, B
PMOD/WRC, Davos, CH
MPS, Lindau, Germany
PTB, Berlin, Germany
BISA, Uccle, Belgium

ESA, HQ, Paris F and ESTEC, Noordwijk, NL
NRL, Washington, USA
NIST, MD, USA
Amano Lab, Japan
LPI, Moscow, Russia
UCL, LLN

Grants used for this research:

ESA/PRODEX Contract C90209 "LYRA preparation to Exploitation".
ESA/PRODEX Contract C90205 "SIDC Data Exploitation".

Visitors: 4

B.2.6. Publications

B.2.6.1. Publications with peer review

A.BenMoussa, **A. Theissen**, F. Scholze, **J.F. Hochedez**, U. Schühle, W. Schmutz, K. Haenen, Y. Stockman, A. Soltani, D. McMullin, R.E. Vest, U. Kroth, C. Laubis, M. Richter, V. Mortet, **S. Gissot**, **V. Delouille**, **M. Dominique**, S. Koller, Z. Remes, R. Petersen, M. D'Olieslaeger, J-M Defise.*Performance of diamond detectors for VUV applications*
Nuclear Instruments and Methods A (2005)

A.BenMoussa, **J.F. Hochedez**, U. Schühle, W. Schmutz, K. Haenen, Y. Stockman, A. Soltani, F. Scholze, U. Kroth, V. Mortet, **A. Theissen**, C. Laubis, M. Richter, S. Koller and J-M Defise.
Diamond detectors for LYRA, the Solar VUV radiometer on board PROBA2, Diamond and Related Materials (2005)

Hochedez J.-F., Schmutz W., Nesladek M. , Stockman Y., Schühle U., **BenMoussa A.**, Koller S., Haenen K., **Berghmans D.**, Defise J.-M., Halain J.-P., **Theissen A., Delouille V.**, Slemzin V., Gillotay D., Fussen D., **Dominique M.**, Vanhellemont F., McMullin D., Kretzschmar M., Mitrofanov A., **Nicula B.**, **Wauters L.**, Roth H., Rozanov E., Rüedi I., Wehrli C., Amano H., **VanderLinden R., Zhukov A., Clette F.**, Koizumi S., Mortet V., Remes Z., Petersen R., D'Olieslaeger M., Roggen J., Rochus P.
LYRA: the Solar UV radiometer aboard the ESA Proba2
Advances in Space Research, Volume 37, Issue 2 , 2006, Pages 303-312, Received 22 October 2004; revised 20 July 2005; accepted 17 October 2005. Available online 7 December 2005

B.2.6.2. Publications without peer review

G. Lawrence, D. Berghmans, J.-F. Hochedez, A. BenMoussa, J.-M. Defise, **V. Delouille,**
M. Dominique, A. Katsiyannis, J.-H. Lecat, **B. Nicula**, W. Schmutz, V. Slemzin & **A. Theissen**
Space Weather with ESA's PROBA2 mission
SOHO-16/Solar Wind 11 Conference, Whistler, BC, Canada 13-17 June 2005.

J.-F. Hochedez, B. Berghmans, J.-M. Defise, S. Poedts & A. de Groof, D. Gillotay & D. Fussen et al
Science goals of LYRA & SWAP
Talk by JFH at the FNRS contact point meeting (2005/03/11)

Véronique Delouille, J.-F. Hochedez, P. Fryzlewicz, **A. BenMoussa**, **M. Dominique, A. Theissen:**
LYRA: The Large Yield Radiometer onboard the ESA PROBA2
EGU Meeting, Vienna, 24-25 April 2005 (presentation by VD

B.2.6.3. Publications in press, submitted

A. BenMoussa, U. Schühle, F. Scholze, U. Kroth, K. Haenen, T. Saito, J. Campos, S. Koizumi, C. Laubis, M. Richter**, A. Theissen** and **J.F. Hochedez.**
Radiometric characteristics of new diamond pin-photodiodes
Measurement Science and Technology (2006), accepted, expected online April 2006

B.2.6.4. Reports, thesis, etc

Fussen D., **Hochedez J.-F.,** Antoine J.-P., Fromm M., Vanhellemont F., **Dominique M.**
DAECA : Detection of Antarctic Exotropospheric Clouds and Aerosols (July) (failed)
Proposal submitted in the field of the Research Programme, Science for a Sustainable Development

Berghmans, Hochedez et al
SCSL proposal to ISSI: submission 18/3, contract, 9/12 (succeeded)
Proposal to ISSI, Bern

Berghmans, Hochedez, Katsyiannis
Proba2 Science Management Plan
Proba2 project document to ESA

Benmoussa, Hochedez
2 Calibration Plans : GI & NI (May)
LYRA Project document

Benmoussa, Hochedez
5 Calibration reports: 2 GI (January & July) & 3 NI (January, July and August)
LYRA Project document

Schuehle, Hochedez
ROB-MPS-PTB-CSL Letter of Agreement: 22/9
LYRA Project document

Hochedez, Benmoussa, Schühle, Stockman
MSM open letter to PRODEX (22/3)
LYRA Project document

Hochedez et al
LYRA detectors Traceability agreement
LYRA Project document

Benmoussa, Hochedez
MSM reprocessing – 3 reports in 2005: 11/5, 23/6, 25/11
LYRA Project document

And many other project documents

B.2.7. Missions

Research missions: 1
Field missions: 14

B.3. Solar cycle studies

B.3.1. Objectives

Since 1996, the EIT telescope on board SoHO observes the Sun in four EUV wavelengths. The analysis of coronal variability in EUV imaging data can bring unique insights on the complex solar dynamo(s). It

is also a topic for Solar Terrestrial relationships through the modeling of irradiance. The image processing and statistical techniques developed for cycle studies are often useful to the solar weather forecast.
Also the LASCO coronagraphs onboard SOHO now span a full solar cycle of information on the solar outer corona and the behaviour of CMEs. Therefore also the analysis over long-time range of LASCO data is an important objective.

B.3.2. Progress and results

Among others, multiscale methods can exploit the wealth of the large EIT archive. We have used the wavelet spectrum, and showed how it can be applied in the long-term study of the solar corona. Applied on He II EIT images, it is able to extract a characteristic scale of the network. This advanced technique is also very sensitive to flares (down to B level) in coronal EIT images.
A new paper was written with Dr Roman Brajsa and accepted. We have analyzed the centre-to-limb function and latitudinal distribution of coronal bright points, from 4 June 1998 to 22 May 1999. An indication of a two-component latitudinal distribution of coronal bright points was found. Possible implications for the interpretation of the solar differential rotation are discussed.
A new technique based on fuzzy clustering was studied to automatically segment EUV solar images into the usual quiet sun (QS), coronal holes (CH) and active regions (AR).
The package for automated detection of CMEs (CACTus) developed in the SECCHI project was successfully applied to the full archive of LASCO data.

B.3.3. Perspective for following years

The flare extractor based on the wavelet spectrum is ready to be made operational (real-time and archive reprocessing). In 2006, Movatrac and the fuzzy clustering are reaching the maturity to be run on the archive. Movatrac could detect precisely the oscillations of the differential rotation parameters. A new collaboration is being set up in order to interpret the trend discovered in the network scale.
A renewed version of CACTus will again be applied to the full archive of LASCO images.

B.3.4. Personnel involved

S. Gissot, JF Hochedez, D. Berghmans, G. Lawrence, V. Delouille, E. Robbrecht, R. Van der Linden

B.3.5. Partnerships

List of national and international partners:

UCL, LLN, B
CEREMADES, Paris Dauphine, F
NRL, Washington DC, US

Grants used for this research:

ESA/PRODEX Contract C90192 “SIDC Telescience”.
ESA/PRODEX Contract C90205 “SIDC Data Exploitation”.
ESA/PRODEX Contract C90131 “SECCHI Exploitation”.

Visitors: 3

B.3.6. Publications

B.3.6.1. Publications with peer review

V. Delouille, J. de Patoul, **J.-F. Hochedez**, L. Jacques, and J.-P. Antoine
Wavelet spectrum analysis of EIT/SoHO images

Solar Physics, 228(1), pages 303-323.

Brajsa, R.; Wöhl, H.; Vrsnak, B.; Rusdjak, V.; **Clette, F.; Hochedez, J.-F.;** Verbanac, G.; Temmer, M.
Spatial Distribution and North South Asymmetry of Coronal Bright Points from Mid-1998 to Mid-1999
Solar Physics, Volume 231, Issue 1-2, pp. 29-44

B.3.6.2. Publications without peer review

D. Berghmans, E. Robbrecht, O. Podladchikova, S. Gissot, V. Delouille, J.F. Hochedez
Computational techniques for automated CME reporting (talk by David Berghmans)
HPC WISER Workshop on Computing in Space and Astrophysical Plasmas, Leuven

V. Barra, **V. Delouille, J.-F. Hochedez**, P. Chainais
Segmentation of EIT Images Using Fuzzy Clustering: a Preliminary Study (Poster)
11th European Solar Physics Meeting (see below)

V. Barra, **V. Delouille, J.-F. Hochedez**, P. Chainais
Segmentation of EIT Images Using Fuzzy Clustering: a Preliminary Study
Proceedings of the 11th European Solar Physics Meeting "The Dynamic Sun: Challenges for Theory and Observations" (ESA SP-600). 11-16 September 2005, Leuven, Belgium. Editors: D. Danesy, S. Poedts, A. De Groof and J. Andries. Published on CDROM., p.77.1

B.3.6.3. Publications in press, submitted

Robbrecht, E., Berghmans, D., Van der Linden R.A.M.
Objective CME detection over the Solar Cycle: a first attempt
Advances in Space Research, *in press* (2005), doi:10.1016/j.asr.2005.02.005

V. Delouille, M. Jansen, R. von Sachs,
Second generation wavelet denoising methods for irregularly spaced data,
accepted to be published in Signal Processing (2005).

B.3.6.4. Reports, thesis, etc

B.3.7. Missions

Research missions: 2

C. Space Weather

The mission of the Royal Observatory of Belgium (ROB) is twofold: it includes both the expansion of knowledge through scientific research *and* the valorization of this knowledge through the provision of a public scientific service. These two aspects meet supremely in the emerging scientific discipline called *Space Weather*, which studies the variable environment of the earth in space and the consequences this can have for human society and technology.
Solar activity is the main driver of space weather. The Earth is orbiting within the outer atmosphere of our home star, the sun. Despite its apparent invariable, simple, spherical shape, we now know that the Sun is variable in many ways. Energetic solar phenomena such as flares and coronal mass ejections have an impact on the space environment of the Earth through different physical connections. Solar activity spans a wide range of timescales, from the secular modulation of the well-known 11-year solar activity cycle, over the 27 days of solar rotation, down to sub-second timescales during eruptions. Monitoring this solar activity and evaluating its likely consequences for the near-Earth environment thus requires both a long-

term commitment as well as daily dedication to follow up the ongoing dynamics in the solar atmosphere. Only a permanent service center that specializes in solar monitoring and solar activity research and that has extensive access to solar data can span these wide requirements. The 'Solar Influences Data analysis Center' at the ROB performs this task within several international networks. The SIDC undertakes to provide expert and timely information on and assessment of solar dynamics and its likely relevance for the Earth environment to an extensive set of users of the service.

Figure 5: A complex, active sunspot group observed on 30 March 2001 in white light by the ground-based telescope of the SIDC.

White-light observations of the solar photosphere are a simple but important way to characterize solar activity. The 11-year solar activity cycle is the most prominent source of solar variability. The existence of this cycle has been known for centuries due to observations of sunspots on the solar surface. The sunspot index is the oldest solar index measuring solar activity and is used for many studies on the cyclical behaviour of the Sun. Elsewhere in this report we describe our contribution to the long-term monitoring of this cycle.

Sunspots provide a good measure for the solar activity cycle, but certainly do not constitute its most relevant manifestation. During solar maximum, the sun generates a large number of energetic eruptions such as solar flares. Solar flares produce intense electromagnetic radiation and high-energy particles, and may be associated with global plasma expulsions from the solar corona known as Coronal Mass Ejections (CMEs). These have the potential of causing severe damage to human technology in space and on the ground and to hamper communication systems. Increased fluxes of high-energy particles, for example, are detrimental for Earth-orbiting satellites and expose airplane crews and passengers to enhanced doses of radiation. Disturbances in the solar wind interact with the Earth's magnetosphere, causing geomagnetic storms that, amongst other things, disturb GPS signals. All these effects form part of what is now commonly called 'Space Weather'. The SIDC operates a service to help users reduce the impact of space weather on activities of human interest. Since 1 Jan 2000, the SIDC has become a *Regional Warning Center* of the International Space Environment Service (ISES) and in this capacity provides short-term (3-day) forecasts of solar activity and its impact on the space environment of the Earth (see below in Project 2 for more detail).

In 2003, ESA started to set up the Space Weather European Network (SWENET) in an effort to initiate the construction of a global space weather service in Europe. This was justified by an earlier study highlighting the strong fragmentation of space weather activities in Europe. The solar physics department of the ROB successfully applied to become one of the Service Development Activities of SWENET. In the framework of this ESA-funded Space Weather Applications Pilot Project, our daily solar monitoring and forecasting activity has been extended and diversified, e.g. by developing a user-friendly interface to solar data, the Solar Weather Browser. These activities are described below in the first Project in this theme.

White-light sunspot observations help in predicting energetic solar events, but today, thanks to space missions such as e.g.

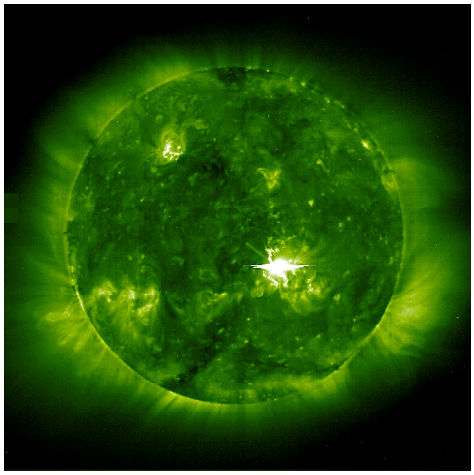


Figure 6: A bright solar flare, captured by the instrument EIT on 1998 May 2.

SOHO, GOES and ACE, a much wider range of observations is available to characterize the solar variability on the level of radiation, particle fluxes, and plasma flows. CMEs, for example, are now routinely registered by the LASCO coronagraph (see below). The availability of these data paves the way to base the Space Weather service provision on more firm scientific footing. Scientific studies described in the other sections of this report from part of this effort, and so does a scientific collaboration set up in the frame of the INTAS scheme (project 3).

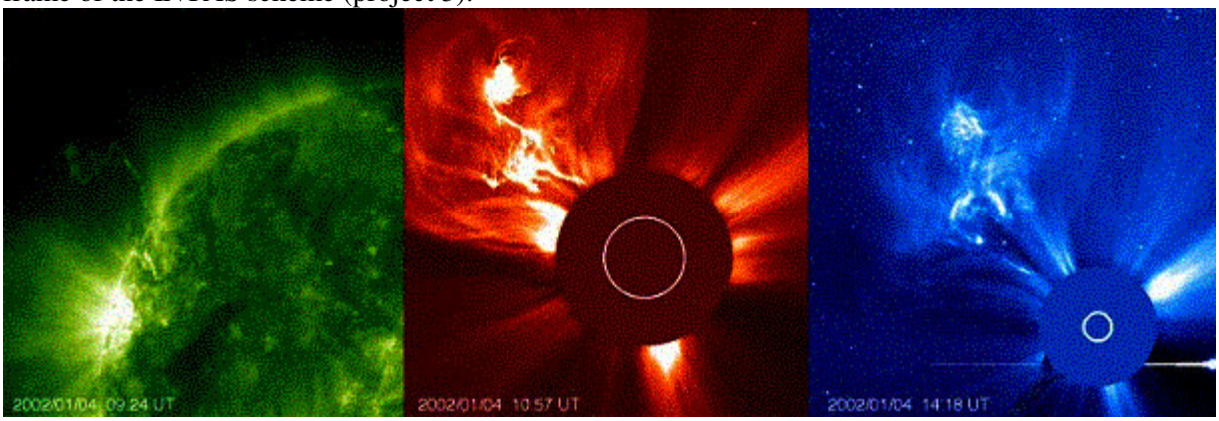


Figure 7: A solar eruption, captured by the EIT and LASCO instruments onboard the joint ESA/NASA space mission SOHO on Jan. 4 2002.

Of particular relevance to future Space Weather research and monitoring in our group is the upcoming PROBA2 space mission (to be launched in 2007), with the solar instruments SWAP and LYRA (described elsewhere in this document). These instruments will lead to much more detailed diagnostics of flares and related phenomena such as EIT waves. From these, we may hope to achieve a much better understanding of the initiation processes of flares and CMEs, and thus, when supplemented by adequate theoretical research and modeling, a much better predictability of solar activity as a whole.

C.1. Participation in the ESA Space Weather Applications Pilot Project

C.1.1. Objectives

In 2002, the SIDC successfully applied to become one of the Service Developments Activities (SDA) of ESA's Space Weather Applications Pilot Project. To this purpose we established a collaboration between several research units within the Space Pole. The purpose is to contribute our expertise in solar observations, solar activity research and space weather monitoring to support the activities of the other groups participating to our own SDA and to the global SWENET network, and to develop tools to automatically detect solar events relevant for space weather. The funding of the project ended April 2005. The routine activities of this project were incorporated in the activities of the RWC (see below).

C.1.2. Progress and results

In 2004, we turned to the 'service and evaluation provision' phase in the Space Weather Applications Pilot Project, which we finished in the course of 2005. All major developments were completed in 2004. Minor additions and upgrades of the products developed still continued throughout the last phase of the project.

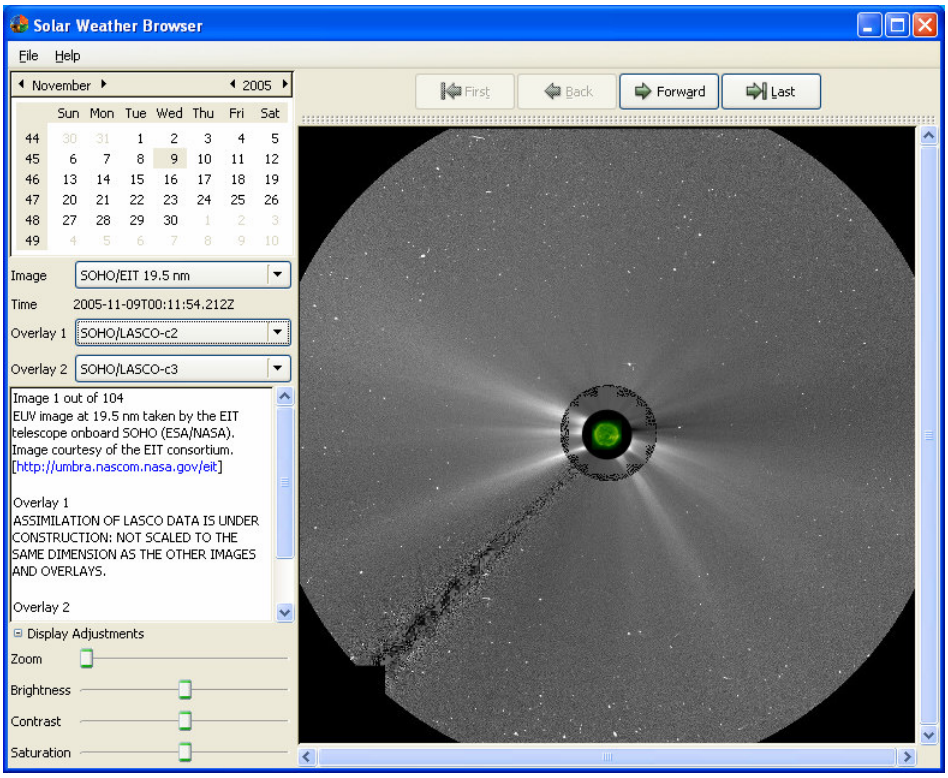


Figure 8: A screenshot of the Solar Weather Browser, here showing how it can be used to visually relate EUV solar images (from EIT) with LASCO-C2 and LASCO-C3 to have a complete field of view from the solar disk up to 32 solar radii.

One of the deliverables under the project is the Solar Weather Browser (SWB), a first version of which was completed early in 2004, but which has since then been further improved. The SWB is a software tool developed by the Royal Observatory of Belgium for easy visualization of solar images in combination with any context information that can be overlaid on the images and that is space weather relevant. It consists of 3 developments: (1) the SWB backend server (SWB-server), (2) the SWB user interface and (3) the SWB download and user support website. The backend server collects data from a variety of sources using different protocols. After acquiring the data, the backend server pre-processes the different types of data with specialized software and makes them available on the distribution website. In this way, the user does not need detailed information on the location and accessibility of the data, nor on specialized software required. The splitting of the SWB in a user interface and a backend server has the additional advantage that new types of data can be included without the need to re-distribute the user interface. In 2005, the SWB client program was improved. Coronograph overlays were introduced and enhancements of the user interface and optimizations of the internals were implemented.

The software package *CACTus* was developed for automated and objective detection of Coronal Mass Ejections (CMEs) in coronagraph images. This development took place for a large part outside of the current project, but in view of the direct relevance of fast detections of CMEs for space weather operations, we implemented this software package in a fully automated data stream to generate near-real-time alerts of significant halo CMEs. This implementation has been fully operational during the second half of the past year. A monthly evaluation of its real-time performance is included in the '*SIDC Monthly Bulletin of Solar and Geomagnetic Activity*', focusing on the email-alerts which it sends out. Whenever a CME larger than a critical threshold is detected an email is sent to registered users.

In this project, we established a close collaboration with Dr. R. Warnant and his co-workers in the GPS section of the Observatory. This group has specialized in scientific studies of the influence of ionospheric perturbations (which may be caused by space weather events) on the accuracy of GPS positioning. A *near-real-time assessment of GPS accuracy*, available through their website did already exist since 2004. In 2005, an operational model to *forecast* geomagnetic disturbances by predicting the local K-index of Dourbes has also been developed and implemented on our web site. These GPS products are fully integrated in the SIDC space weather service by a fully automated alerting service when strong deterioration of GPS accuracy is observed or expected.

An evaluation of the quality of the SIDC forecasts, by comparing those with alternative methods derived from statistical studies and physics-based event estimators was done for the whole period of the project. This study will not only help us improve the future forecasting techniques, but should also lead to a better knowledge about the precise causes of short-term variability in solar indices (such as the 10cm radio flux) and about the changes in global space weather event distributions over the solar cycle. This study was handed over to the Space Weather European Network (SWENET) to be integrated in their services and evaluation of the offered products. SWENET gathers most information from other SDA's and makes it available. Through the SWENET website (http://www.esa-spaceweather.net/swenet/index.html), one can register to receive our products.

In April 2005, the project ended. A final report, including a business plan was written. The final report includes a complete overview of the start, the achievements and evaluation of the project. The business plan concentrates on the used resources, the commercial potential of the products and services and the future plans in case of (no) extended funding. A final presentation as SDA in SWENET was given at the second European Space Weather Week in ESTEC, Nov. 2005. We supported the cost benefit analysis ordered by ESA, which will have to establish whether there is sufficient interest in space weather throughout Europe to support a continuation of this type of project in the long term. The results of this report are not available yet. The SIDC project was successful in many aspects. The positive collaboration between the three institutes of the Space Pole, ROB, RMI, and BISA led to important progress in the creation of a comprehensive space weather service. The SIDC as an RWC became more visible and up-to-date through some products specifically set up for the general public. The number of users grew drastically since the start of the project. SIDC data was used as input to other SDAs. There was a successful and satisfactory collaboration with several of them leading to the development of specific products, even after the term of the project. At the end of 2005, the Estimated International Sunspot Number (EISN) was produced on request of the users.

C.1.3. Perspective for next years

The project finished in April 2005. The services are continued for at least one year, as contractually foreseen. This is also done in the framework of the SIDC as a Regional Warning Center (RWC) of the ISES. The forecast evaluation procedure initiated is expected to lead to further scientific studies of the relationship between solar EUV radiation and solar radio fluxes. Also, statistical studies of solar flare distributions and their variation over the solar cycle will still be performed. The event detection tools will be further developed to build event catalogues than can be correlated with solar activity indices and that will assist scientific studies of the solar origins of space weather disturbances. This will be done in the framework of other running projects, e.g. online CME catalog for STEREO/SECCHI. Furthermore, these tools will be used to assist in the management of the large volumes of solar data that is expected to become available in the coming years, e.g. for the reduction of telemetry requirements for space missions by selecting the most relevant images to downlink.

C.1.4. Personnel involved

Project Manager: Ronald Van der Linden

People hired on the project grant: P. Vanlommel.
Additional contributions from: David Berghmans, Frederic Clette, Andrei Zhukov, Bogdan Nicula, Laurence Wauters, Sarah Willems, E. Robbrecht, Gareth Lawrence.

C.1.5. Partnerships

List of national and international partners

- This project is a collaboration between the Royal Observatory of Belgium (solar physics and GPS groups), the Royal Meteorological Institute, the Belgian Institute for Space Aeronomy, and Creaction Int.
- Our service forms part of the global European network linking up the various projects (SWENET, see http://esa-spaceweather.net/swenet/index.html).
- The Space Weather Working Team (SWWT) contributes to the coordination of European space weather projects (see http://www.estec.esa.nl/wmwww/WMA/spweather/esa_initiatives/swwt/).

Grants used for this research

ESA contract 16913/03/NL/LvH.

Visitors: 2, in addition to the presence of typically 4-6 scientists from the other participating institutes at the monthly local progress meetings.

C.1.6. Publications

C.1.6.1. Publications with peer review

C.1.6.2. Publications without peer review

Van der Linden R., Vanlommel P., Berghmans D., Robbrecht E., Clette F., Nicula B., Zhukov A., Wauters L., Warnant R., Pottiaux E., Lejeune S., Barre A., Bavier M., Nebdi H., Jodogne J.-C., Rasson J., Stegen K., Heynderickx D., Roth M., De Keyser J., Kruglanski M., Henry J.-P., Marche J.P.
The SIDC Project: a comprehensive operational space weather service in Belgium
Poster at the Space Weather Week, Boulder, 5-8 April 2005.

Van der Linden R., Vanlommel P., Berghmans D., Robbrecht E., Clette F., Nicula B., Zhukov A., Wauters L., Warnant R., Pottiaux E., Lejeune S., Barre A., Bavier M., Nebdi H., Jodogne J.-C., Rasson J., Stegen K., Heynderickx D., Roth M., De Keyser J., Kruglanski M., Henry J.-P., Marche J.P.
The SIDC Project: a comprehensive operational space weather service in Belgium, final report
Poster at the European Space Weather Week, ESTEC, Noordwijk, 13-16 November 2005.

See also publications 'RWC'

C.1.6.3. Publications in press, submitted

C.1.6.4. Reports, thesis, etc

Vanlommel P., Van der Linden R.
Final Report: Evaluation of SIDC forecast/services, submitted to ESA
Contractual report to ESA, 16 pages.

Vanlommel P., Van der Linden R., Stegen K., **Warnant R.**
Final Report, submitted to ESA
Contractual report to ESA, 132 pages.

Vanlommel P., Van der Linden R.
Executive Summary Report, submitted to ESA
Contractual report to ESA, 26 pages.

Vanlommel P., Berghmans D., Van der Linden R.
Business plan, submitted to ESA
Contractual report to ESA, 10 pages.

Warnant R.
Final Report: Contacts with GPS users for evaluation and improvement of the services, *submitted to ESA*
Contractual report to ESA, 9 pages.

Van der Linden R.
Final Report: Production solar messages, submitted to ESA
Contractual report to ESA, 9 pages.

Van der Linden R., the SIDC team
Monthly progress reports to ESTEC for the ESA Space Weather Applications Pilot Project.

R. Van der Linden, P. Vanlommel ,D. Berghmans, E. Robbrecht, F.Clette, B. Nicula, A. Zhukov, L. Wauters, R. Warnant, E. Pottiaux, S. Lejeune, A. Barre, M. Bavier, H. Nebdi, J.-C. Jodogne, J. Rasson, K. Stegen, D. Heynderickx, M. Roth, J. De Keyser, M. Kruglanski, J.-P. Henry, J.F. Marche
The SIDC project: a comprehensive operational space weather service in Belgium
Poster presentation at the European Space Weather Week, ESTEC, Nov. 29 - Dec. 03 2004.

C.1.7. Missions

Research missions (visits and conferences): 5
Operational missions (commissions, working groups): 2
Field missions (observations, station maintenance): 0

C.2. Operational activities as Regional Warning Center (RWC) Belgium

C.2.1. Objectives

RWC Belgium offers a permanent service center, specializing in solar monitoring and solar activity forecasting under the auspices of the ISES network. For this, we have access to a large volume of solar and heliospheric data that can span these wide requirements. Building on insights derived from our scientific studies, the SIDC provides expert and timely information on and assessment of solar dynamics and its likely relevance for the Earth and human technology.

C.2.2. Progress and results

The main task of the SIDC as Regional Warning Center of the ISES is to perform continuous monitoring of solar and geomagnetic activity, which includes daily forecasts of several internationally recognized activity indices. The role as a RWC implies handling data flows from various sources, most of them arriving through e-mail or internet downloads. To perform these activities in an efficient way, we use the locally developed software packages 'PreviMaster' and 'PreviWeb', which are continually improved and adapted to changing data sources and user requirements. Both software packages were significantly extended during 2005 under the impulse of the joint development of user products for the ESA Space Weather Applications Pilot Project. During 2004, we have also replaced the servers that handle SIDC data, at the same time implementing tighter security constraints and a more structured network. The PreviWeb interface has been completely rewritten by linking it up to scripts populating a MySQL database.

This SIDC database includes recorded data since 2001 and forecast data since March 2003. It is linked to other databases containing references to solar data and event catalogues derived from this data.

Reports and forecasts of solar activity and space weather conditions are distributed every day (including weekends and holidays) at approximately 12:30 UT in the 'ursigram' messages. Weekly summaries are sent out in principle on Mondays, while more extensive monthly summaries of solar and geomagnetic activity are included in the Sunspot Bulletin of the SIDC. Besides these default distributions, several other types of messages are generated, the most important ones being the fast alerts discussed earlier like the all-quiet-alert which becomes more relevant approaching solar minimum, and the 'presto' messages, which are intended to alert our users of strong perturbations to space weather. When conditions warrant, press contacts are also established. The main method of information distribution is through the internet: the SIDC website and e-mail. The growing international interest in our service is reflected in the steady growth in the website visits and e-mail registrations.

```
SOLAR FLARES  : Eruptive (C-class flares expected, probability >= 50%)
GEOMAGNETISM  : Quiet (A<20 and K<4)
SOLAR PROTONS : Quiet
PREDICTIONS FOR 20 Dec 2005  10CM FLUX: 088 / AP: 019
PREDICTIONS FOR 21 Dec 2005  10CM FLUX: 086 / AP: 005
PREDICTIONS FOR 22 Dec 2005  10CM FLUX: 082 / AP: 001
COMMENT: The solar wind speed has been systematically rising in the
last 24 hours and is currently at 600km/s. We presume that this is due
to the influence of small coronal hole half way between active regions
NOAA837 and NOAA835. We expect that the influence on geomagnetic
conditions will in any case remain small. As of today, we start with a
new data product, the 'Estimated International Sunspot Number', which we
will distribute through these daily messages. Note also the link at the
bottom of this message where you can find more information.


ESTIMATED ISN       : 041, BASED ON 02 STATIONS.

SOLAR INDICES FOR 19 Dec 2005
SUNSPOT INDEX       : 069
10CM SOLAR FLUX     : 090
AK CHAMBON LA FORET : 018
AK WINGST           : 014
ESTIMATED AP        : 013
ESTIMATED ISN       : 044, BASED ON 04 STATIONS.

NOTICEABLE EVENTS SUMMARY
DAY BEGIN MAX  END  LOC    XRAY OP  10CM RADIO BURST TYPES     Catania NOAA NOTE
NONE
END
```

Figure 9 The first ursigram sent which included the Estimated ISN. This was announced through the 'Solar Highlights' on Dec. 20, 2005.

End 2005, we started with an electronic version of the SIDC Monthly Bulletin of Solar and Geomagnetic Activity. Typically around the 7th of the month, an email is sent to the registered users with the information where the electronic version of the bulletin can be found.

On user request, the Estimated International Sunspot Number was developed. Previweb is adapted in that sense that this EISN is now sent together with the daily ursigrams (see). The observations used to calculate the EISN reach us through the newly developed Wolf Interface. Observers have to give their input before 12:30UT. A statistical reliable method was developed and is run by previmaster. Typically 4 to 5 stations contribute. The 'Solar Highlights' are used to make publicity and to attract more stations.
An evaluation on the performance of the SIDC as Regional Warning Center during the September 2005 events was made. The fast alert service did well. The results were presented during the Second European Space Weather Week in ESTEC.

C.2.3. Perspective for next years

The SIDC will continue its activities as a Regional Warning Center of the ISES. However, since the ESA pilot project formally ended in March 2005, and ESA did not extend the project, activities will probably be reduced to a lower level. We will continue to strengthen our scientific research as the solid basis of our space weather forecasting activities. The SIDC activities will benefit from a strong participation of the solar physics department team in space missions such as PROBA2 and STEREO, and from a participation in international research networks.

This number of stations contributing to the EISN will steadily grow as more observers start to know the Wolf Interface and the relevance of the EISN. In April 2006, a seminar for amateur astronomers is

planned. This opportunity will be used to urge them to use the available facilities. A forecast of one day ahead of the EISN will be developed and sent together with the daily ursigrams.

C.2.4. Personnel involved

Project leader: Ronald Van der Linden
Additional contributions from: D. Berghmans, F. Clette, G. Lawrence, E. Robbrecht, P. Vanlommel, A. Zhukov, S. Willems, L. Wauters, B. Nicula, J.-F. Hochedez, O. Boulvin, D. Lafont.

The daily duty cycle of forecasting and monitoring activities were shared by D. Berghmans (53), F. Clette (48), G. Lawrence (27), R. Van der Linden (31), E. Robbrecht (75), P. Vanlommel (85) and A. Zhukov (46).

C.2.5. Partnerships

List of national and international partners

RWC Belgium is one of the nodes in the International Space Environment Service (ISES, see http://www.ises-spaceweather.org/).

Grants used for this activity:

ESA/PRODEX Contract C90192 “SIDC Telescience”.
ESA/PRODEX Contract C90205 “SIDC Data Exploitation”.

Visitors: None.

C.2.6. Publications

C.2.6.1. Publications with peer review

Hochedez J.-F., Zhukov A., Robbrecht E., Van der Linden R., Berghmans D., Vanlommel P., Theissen A., Clette F.
Solar weather monitoring
Annales Geophysicae, 23, issue 9, pp. 3149-3161, 2005.

Berghmans D., Van der Linden R., Vanlommel P., Warnant R., Zhukov A., Robbrecht E., Clette F., Podladchkova O., Nicula B., Hochedez J.-F., Wauters L., Willems S.
Solar activity : nowcasting and forecasting at the SIDC
Annales Geophysicae, 23, issue 9, pp. 3115-3128, 2005.

C.2.6.2. Publications without peer review

C.2.6.3. Publications in press, submitted

C.2.6.4. Reports, thesis, etc

R.A.M. Van der Linden and the SIDC team.
Annual report 2005 to the International Space Environment Service.

The SIDC team
Outgoing messages from RWC Belgium: e.g. 365 daily ursigrams, 52 weekly bulletins, 2 Monthly Bulletin of Solar and Geomagnetic Activity (since Nov. 2005), 2 quarterly bulletins, 12 Monthly Ri Reports, 12 Monthly Ri_hemispheric Reports, all-quiet-alerts, 79 presto alerts, halo CME alerts, GOES X-ray flare detection alert, reduced GPS accuracy alert, advance alert: enhanced geomagnetic activity warning. The alerts are sent when needed, the other bulletins are sent on a regular basis.

C.3. INTAS Project 03-51-6206 "Solar and interplanetary disturbances causing severe geomagnetic storms"

C.3.1. Objectives

The investigations in the framework of this project (started in 2004) are carried out in collaboration with Max-Planck-Institut für Sonnesystemforschung (Germany), Skobeltsyn Institute of Nuclear Physics (Russia), IZMIRAN (Russia) and Astronomical Institute (Czech Republic). The objective of the project is to study the strongest geoeffective disturbances in the corona and inner heliosphere that occurred during the current solar cycle.

C.3.2. Progress and results

The solar and interplanetary sources of extreme solar events of October – November 2003 and November 2004 have been identified using data from SOHO (EIT and LASCO), CORONAS-F (SPIRIT) and ACE spacecraft. A comparison of the solar atmosphere observations obtained by EIT and SPIRIT has been performed. It has been demonstrated that global changes occurred in all spectral ranges of the solar electromagnetic radiation with the asymmetry in the heliologitude. This phenomenon was accompanied by more localized enhanced energy releases, manifested as CMEs and flares. The most powerful of them were observed on the side of the Sun that was brighter even without these local enhancements. These results suggest that the physical causes of solar and heliospheric phenomena in October – November 2003 are not exclusively local and do not belong only to active regions and solar atmosphere above them. The energy supply and driving forces probably have a more global nature.

During the visit of I. S. Veselovsky (Skobeltsyn Institute of Nuclear Physics) to the ROB (10-23/04/05) some space weather studies were performed. It has been shown that the temporal profile of the Dst index for extreme geomagnetic storms follows quite well the changes of the north – south component (Bz) of the interplanetary magnetic field. The quantitative description is still a challenge, but it seems now clear that the supply of free energy from inside the magnetosphere is quite weak and geomagnetic storms can be triggered only by external disturbances, i.e. perturbations in the solar wind.

C.3.3. Perspective for next years

The project is financed for three years (2004 – 2006). The investigation of solar and interplanetary sources of severe geomagnetic storms will be continued. The sources of more recent severe storms that occurred in January, May and September 2005 will be identified and these storms will be compared to other extreme events.

C.3.4. Personnel involved

Team Lead: A. Zhukov
Additional contributions from: R. Van der Linden

C.3.5. Partnerships

List of national and international partners

This research project is a collaboration between 5 scientific institutes.

Grants used for this research:

INTAS grant 03-51-6206

Visitors: none.

C.3.6. Publications

C.3.6.1. Publications with peer system

Veselovsky, I.S., Dmitriev, A.V., Zhitnik, I.A., **Zhukov, A.N.**, Zel'dovich, M.A., Kuzin, S.V. Naumkin, A.A., Persiantsev, I.G., Ryazanov, A.Yu., Shugai, Yu.S., Yakovchuk, O. S., Bogachev, S. V., Shestov, S.V.
Global Variations and Asymmetry of the Sun During Extremely High Activity in October–November 2003.
Solar System Research, Vol. 39, No. 3, 2005, pp. 169-175.

Veselovsky, I.S., Bothmer, V., Cargill, P., Dmitriev, A.V. Ivanov, K.G. Romashets, E., **Zhukov, A.N.**, Yakovchouk, O.S.
Magnetic storm cessation during sustained northward IMF.
Advances in Space Research 36 (2005) 2460-2464.

Slemzin, V.A., Kuzin, S.V., Zhitnik, I.A., Delaboudinière, J.-P., Auchere, F., **Zhukov, A.N.**, **Van der Linden, R.**, Bugaenko, O.I., Ignat'ev, A.P., Mitrofanov, A.V., Pertsov, A.A., Oparin, S.N., Stepanov, A.I., Afanas'ev, A.N.
Observations of Solar EUV Radiation with the CORONAS-F/SPIRIT and SOHO/EIT Instruments.
Solar System Research, Vol. 39, No. 6, 2005, pp. 489-500.

C.3.6.2. Publications without peer system

C.3.6.3. Publications in press, submitted

C.3.6.4. Reports, thesis, etc

C.3.7. Missions

Research missions: 0
Operational Missions: 1
Field missions: 0

D. Solar activity indices

As the World Data Center for the Sunspot Index and a data analyses service of the FAGS, the SIDC is in charge of the determination, archival and mid-term prediction of the International Sunspot Number, the most fundamental solar activity index. Given its unequalled time coverage of three centuries, it is used as a reference index in innumerable studies and publications. Most other indices, introduced more recently, are calibrated on the sunspot number in order to define long-term irradiance models for backwards and forward extrapolations. Along that axis, the solar physics team has developed internally new researches in the domain of solar indices to extend the base sunspot reference.

The optical USET instruments are providing visual and CCD observations in support to the SIDC sunspot index determination, as one of the reference stations in the worldwide network. The introduction of white-light and Hα CCD imagers, now in routine use, marks also an ongoing effort to improve and to better understand existing solar activity indices and to study new quantitative ground-based solar indices based on modern electronic imaging technologies.

The Humain station was previously dedicated to the continuous recording of the 600MHz radio flux, one of the few long-term indices preceding the space-era, which is provided only by this station. In the framework of a modernization and redeployment project submitted in 2004 and still awaiting a full evaluation, the Humain radio instruments could record absolute fluxes in other radio bands, including 10.7cm, and provide spectrographic diagnostics of radio bursts in near-real time to support the SIDC services. At the moment, however, radio observations in Humain have been suspended.

Finally, in preparation of the science exploitation of the PROBA2/SWAP imager, a correlative study has been initiated between SOHO/EIT and CORONAS/SPIRIT images and the 10.7 cm radio flux, in order to establish a predictive relationship between the spatially-resolved extreme UV flux and the standard 10cm radio index. The team also prepares UV irradiance variability studies based on the absolute standard fluxes from the PROBA2/LYRA radiometers now in development.

D.1. SIDC, World Data Center for the International Sunspot Index

D.1.1. Objectives

Determination of the International Sunspot Index, based on visual sunspot observations from a world wide network of observing stations. Since 1981, the SIDC maintains and makes accessible to the scientific community the sunspot archive spanning 3 centuries, i.e. the longest existing record of solar activity, previously under the responsibility of the Zurich Observatory. The SIDC also publishes, through its Sunspot Bulletin, various solar indices as well as mid-term activity forecasts.

D.1.2. Progress and results

The normal operations of the SIDC as World Data Centre for the Sunspot Index include:

- Data processing:
  - Determination of the provisional sunspot number (Total and normalized hemispheric North & South counts)
  - Computation of the monthly, smoothed monthly and yearly means.
  - Computation of the definitive sunspot number (Total & hemispheric, published quarterly) based on the entire network
  - Mid-term prediction by the *Waldmeier classical method* and by the *Combined Method*, 18 month ahead.
  - Quality control: long-term drift evaluation based on 20 selected stations and the 10cm radio flux.
- Archive:
  - Maintenance of the archive: yearly, monthly, monthly smoothed and daily sunspot numbers.
  - The archive is publicly accessible through the SIDC Web and FTP site (ASCII data files and plots)
- Sunspot Bulletin (monthly publication):
  - Provisional sunspot table and plot
  - 24-month predictions of the monthly Sunspot Number
  - Summary of the URSIGRAMS, with additional indices (PPSI, 600MHz flux, 2800MHz (10cm) flux, Terre Adélie cosmic ray counts, solar flare index, X-flare index, Wingst geomagnetic index Ak).
  - Uccle daily provisional relative and normalized sunspot numbers derived from the digitized USET drawings.
  - Table of major sunspot groups observed at Uccle and probable return of major groups derived from Uccle sunspot group classification.

- Quarterly SIDC-News issue: SIDC definitive international and Hemispheric Sunspot Numbers for 3 months.

New developments in 2005:

- The SIDC-WDC faced serious problems of understaffing in 2005, due to long term sickness absences of two staff members, a vacant position (since May; new recruitment in progress) as well as the nomination of R. Van der Linden as ROB Director. The continuity of the SIDC services was ensured thanks to the re-assignment of the remaining staff (one scientist, F. Clette and one technician, A. Ergen) and the appointment of P. Vanlommel on a replacement contract.
- This year, a special effort was dedicated to the modernization of the SIDC sunspot processing:
  - Development and preliminary testing of the "WOLF" Web interface: this new tool will allow observers to enter their reports directly into an SIDC database. This interface features consistency checking and will thus speed up the data import step, by strongly reducing the workload of semi-manual error checking. It also opens new possibilities, like the calculation of a daily estimated sunspot number based on a small subset of stations.
  - Start of the rewriting and documenting of the SIDC procedures and programs: this work was suspended in December but full operating manuals were already completed. As a complete renewal of the operators team will occur over the 2006-2008 period (multiple retirements), this effort is necessary to preserve and consolidate the past experience and know-how, also as a base for future redefinitions and expansions of the WDC products and services.
  - Rationalization of the address management, of the report collection and of the bulletin distribution (paper mail, fax, e-mail). The number of addressees receiving free copies of the Sunspot Bulletin was drastically reduced, while at the same time the Bulletin is made available for free in electronic format through the website.
  - Contacts were established with several new observers (mostly amateur astronomers). Indeed, a renewal of the observing network is needed to compensate for unavoidable departures, and a special attention must be devoted to non-European SIDC contributors, in continents and longitudes bands that are still sparsely covered by the SIDC network.
  - At the occasion of the upcoming 25th anniversary of the SIDC's foundation, several papers were prepared or already published to retrace the history of the SIDC and the International Sunspot Index. This was done in collaboration with Dr. A. Koeckelenbergh, founder of the SIDC, who provided important first-hand information, as well as copies of original historical documents.

D.1.3. Perspective for next years

The year 2006 will bring the celebration of the 25th anniversary of the creation of the SIDC in Brussels. The automation of the sunspot index processing will be continued. Observers will be invited to report their observations through the new Web interface of the SIDC. Processing scripts and programs, as well as the associated data flow, will be updated, in connection with the RWC URSIGRAM automated processing. This effort should lead to the publication of a fully up-to-date description of the method leading to the sunspot index determination: an appropriate benchmark after 25 years of SIDC activities. The recruiting of replacement staff for the multiple positions that are currently vacant or will soon become vacant will be crucial to support this major effort. We also expect to add daily estimations of the sunspot number and a short-term forecast of the sunspot index to the daily ursigrams produced by the RWC. Further migration of paper copies to electronic versions of the Sunspot Bulletin will be encouraged. In the longer term, a fundamental revision of the way the sunspot number is calculated should be foreseen.

D.1.4. Personnel involved

Project lead (shared in 2005): R. Van der Linden, F. Clette

SIDC team: A. Vigneron, O. Boulvin, A. Ergen, L. Wauters, P. Vanlommel, G. Evrard, D. Berghmans.

D.1.5. Partnerships

List of national and international partners

The SIDC is one of the World Data Centers in the World Data Center System (http://www.ngdc.noaa.gov/wdc/wdcmain.html)

The SIDC is a data analysis service of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS, see http://www.kms.dk/fags/index.html)

Grants used for this research:

ESA/PRODEX Contract C90192 “SIDC Telescience”.

Visitors (give only the total number)

6 visiting scientists, including some observers of the SIDC network.

D.1.6. Publications

D.1.6.1. Publications with peer review

D.1.6.2. Publications without peer review

The SIDC Team, 2005.
The Sunspot Bulletin (12 issues).

The SIDC Team, 2005.
SIDC News (4 issues).

Berghmans, D. Van der Linden. R.A.M., Vanlommel, P., Clette, F., Robbrecht, E., 2005:
"History of the Sunspot Index: 25 years SIDC",
in Proc. IAGA "Historical event and people in aeronomy, geomagnetism and solar-terrestrial Physics", Ed. W. Schröder, J. Hist. Geophysics and Cosmical Physics, Vol. VII, No.1, pp. 288-299.

Clette, Frédéric, 2005:
"Pierre Cugnon: une vie au soleil"
Ciel et Terre, Vol. 121, No. 1, p. 21 – 22.

D.1.7. Publications in press, submitted

D.1.8. Reports, thesis, etc

The SIDC Team, 2005.
Annual report to FAGS.

D.1.9. Missions

Research missions: 1
Operational Missions: 1
Field missions: 0

D.2. The Uccle Solar Equatorial Table (USET)

D.2.1. Objectives

Optical observations of the Sun for the characterization of its activity and of sources of irradiance variations. This includes visual sunspot observations, digital imaging in white-light (photosphere) and in the H-alpha line (chromosphere) for real-time flare patrol observations. Advanced exploitation of the visual sunspot observations of the Uccle station, and publication in the SIDC Bulletin of additional indices for this reference station (hemispheric and central zone indices, PPSI, individual group evolution).

D.2.2. Progress and results

Maintenance of the CCD camera system: the cameras did not suffer from any major failure in 2005. However, the performance and reliability of the aging cameras is slowly degrading. Therefore, several actions were undertaken:

- Isolated enclosures were installed to protect the cameras from extreme temperatures, from high humidity and from dust.
- A market study was undertaken over the last 3 months of 2005 to select new CCD cameras to upgrade the existing ones (higher resolution 2048x2048 pixels, enhanced blue sensitivity, standard remote PC interface).
- The upgrade of the camera control PC was initiated. The required change in control library software induced some delays, preventing the completion of this upgrade in 2005.

Additional work on the telescopes:

- *The full 2-axis stepping-motor control of the USET mounting* was commissioned on June 15, 2005. The new motorization and control electronics improves the tracking and control of the telescope but it also opens many future possibilities for the computerization and automation of the telescope operation.
- *Initial development of a solar pointer:* Building on the new computer controlled motorization, this device will improve the accuracy of drawings and allow an accurate and controlled centering of the CCD camera system (mechanical drift correction, atmospheric image motion, controlled off-pointing for flat-field sequences). In 2005, the key components were identified and selected (objective lens, filters and 4-quadrant sensor (sensor size and focal length matching, spectral response, sensor response time, etc.). This work will continue in 2006.

New H-alpha optics (LOTTO funding): given the limited quality (resolution and contrast) of the vintage Lyot filter on the USET, it had been decided in 2004 to replace it with a new H-alpha system. In the course of 2005, a new optical system based on a focal Fabry-Pérot monochromator was selected and ordered. The monochromator is a high-uniformity 0.5Å device (vs 0.7 Å for the current filter), with thermal control. Given the long delivery time of the filter, the new H-alpha system will be delivered only in early 2006 and enter normal operation in the second half of 2006, after installation and commissioning.

New digitizing system for the solar drawings: in 2005, the development of a new encoding and digitization software was started in the framework of the training work of a graduate student in computer sciences, Julien Moreau (ESI, 14/2-27/5/2005). Unfortunately, over his 3-month training period, the student could not complete the program. Although the essential components are finished at 80%, the software is

not yet functional. Therefore, the processing of the USET drawings had still to be done manually in 2005. Fortunately, this task remained manageable thanks to the rather low solar activity. The software will be completed in the spring of 2006, with the collaboration of a new ESI graduate student, Julien Rateau.

- Observations:
  - Like in previous years, the CCD synoptic images were automatically transferred to a dedicated archive and the latest images were uploaded to the SIDC servers and were displayed in the "Latest Solar Data" pages, together with imagery from other observatories and spacecrafts, for worldwide access.
  - This year, all Uccle sunspot drawings were scanned immediately after the observations. The scanned document (jpeg file) was included in near-real time in the "Latest Solar Data" web page of the SIDC, together with drawings from the Catania, Locarno and Crimea observatories. Sunspot group evolution data, derived from encoded drawings, were used for the Uccle tables of the Sunspot bulletin (p.4).
  - The 2005 statistics for the sunspot observations are the following:
    - Number of observations: 310 (1 drawing on 182 days, 2 drawings on 64 days)
    - Number of observing days: 246 (out of 365)
    - Number of observers: 15, with mainly O. Boulvin (161 drawings/ 200 days).
  - The 2005 statistics for the CCD observations are the following:
    - White-light (photosphere): 783 images over 215 days (3.6 im/day)
    - H-alpha (chromosphere): 1116 images over 222 days (5.02 im/day)

D.2.3. Perspective for next years

- Instrument development:
  - Installation of the new Hα filter and telescope (and association with the international Hα network).
  - Completion of the new digitizing and encoding software tool for solar drawings.
  - Design study and development of a solar pointer and installation of absolute encoders to ensure accurate tracking for CCD cameras.
  - Selection, purchase and installation of two new 2048x2048 CCD cameras (LOTTO funding)
  - Design and acquisition of a new CaIIK chromospheric telescope (LOTTO funding)
- Full debugging and rewriting of the USET processing software: this effort will allow writing up a structured description of the method. It will also bring improvements and an increased robustness. The know-how can later be applied to other data (digital solar images from Uccle and other sources). The recruiting of replacement staff will be crucial to support this major effort.
- Trainees: over the 2005-2006, academic year, F. Clette will be supervising one student working on the development of the USET instrument and the associated data acquisition (Julien Rateau, ESI)

D.2.4. Personnel involved

Lead: F.Clette (observations, development, testing and calibration of instruments),
Technical maintenance and instrument development: J-L. Dufond, A. Ergen
Data processing: A.Vigneron, G.Evrard, O.Boulvin
Observers: A. Ben Moussa, D. Berghmans, O.Boulvin, F.Clette, M. Dominique, J-L Dufond, A.Ergen, S. Gissot, G.Lawrence, E.Podladchikova, E. Robbrecht, A. Theissen, R. Van der Linden, A. Vigneron, A. Zhukov.

D.2.5. Partnerships

List of national and international partners

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Grants used for this research

- LOTTO grant
- ESA/PRODEX Contract C90192 “SIDC Telescience”.

Visitors (give only the total number):

- 5 groups (1 formal, 4 educational)

D.2.6. Publications

- SIDC sunspot bulletin (12 monthly issues): the Uccle-USET relative and normalized sunspot numbers, large sunspot group table, large returning group list.
- Real-time web distribution of more than 1900 CCD camera images.
- Real-time web distribution of 246 scanned solar drawings.

D.2.7. Missions

Research missions: 2
Operational Missions: 0
Field missions: 0

D.3. The Humain radio-astronomy station

D.3.1. Objectives

Radio-electric observations of the Sun for flare monitoring and long-term recording of the solar radio in the upper-chromosphere and low corona:

- Integrated radio flux at 600 MHz.
- Near-real time transmission and processing of the Humain data, in support to the SIDC solar flare monitoring.
- Future extension to other frequencies: radiometer at 2,8Ghz (10.7cm), decimetric radio-burst spectrograph.

D.3.2. Progress and results

- *Preservation of the Humain site quality*: again this year, a continuous attention had to be devoted to the protection of the perimeter around the station and of the Humain radio frequencies against radio interferences: the Electrabel wind turbine project has been abandoned. The coordination with the CRAF was maintained at the international level (600 and 408MHz bands protection in future ITU regulations, wind turbine issue). We continued to process frequency allocation requests for the IBPT and we maintained contacts with the Lhoist industries concerning the exploitation of their quarry located in the immediate neighborhood of the station.
- Station development and projects: 2005 was a critical year for the Humain station that was never in such an extremely fragile situation because of structural reasons (quick drop of staff after years without replacement) and of the postponement of the evaluation of a modernization project submitted in 2004. The main steps were the following

- Evaluation of the HUMSOLAR project by international radioastronomy experts: The HUMSOLAR project submitted for a BELSPO Action1 funding in April 2004 did not progress in 2005 despite repeated calls and warnings of the critical situation. Following a request of the Scientific Council in June 2004, the project was submitted to the evaluation of ten international experts (directors of radioastronomy facilities and international project PIs) who gave their reports in February 2005. All reports supported the absolute flux and real-time dissemination via the SIDC. One idea was criticized as unfeasible (flare diagnostic by a few discrete frequencies) but another solution was suggested within the same budget envelope: i.e. a full multi-frequency radio spectrograph. The HUMSOLAR project was adapted accordingly. Unfortunately, partly because of the transition phase around the change of ROB director, the evaluation of the project was stopped at the level of the Scientific Council (March 16 meeting).
- Interruption of the observations (August 2005): unfortunately, in the meantime, the new Director concluded that no more funding was available to continue paying the salary of the local electronician, M. Walkiers (contractual), which left the station with only one person to maintain the site and operate the instruments. Consequently, given the case of absolute necessity and considering the safety issues with only one remaining staff member, M. Janssens, at an isolated site, the observations had to be suspended for an undetermined duration in August 2005. In the months that followed, as this state of affairs resulted from practical impossibilities and internal ROB reactions, rather than a fully argued assessment, the whole matter was submitted by F.Clette to the President of the board of BELSPO, M. P. Mettens. who convened a meeting with the leaders of the station (F.Clette, D. Berghmans, R. Van der Linden). As a conclusion, he prompted the scientists in charge of Humain to submit a new development and routine operation plan for this facility. The submission of such a plan, as well as an audit of the site and instruments, is now planned for 2006.

- Observations and instrument status at the end of 2005:
  - The normal observations of the 600MHz solar flux, and also the 27khz SEA recordings, were carried out continuously from January 1st to July 31:
    - 600MHz radiometer: 210 observed days over 212 days of operation.
    - Daily plots including flare events were produced for publication on the SIDC web site (http://www.sidc.oma.be/radio/).
    - The solar background flux was derived and published among reference indices in the SIDC Sunspot Bulletins (p.3, continuation of time series beginning in 1954).
  - On August 1st, all antennas were stopped and since then, are no more rotated on a weekly basis to avoid internal rust buildup in the bearings. Receivers were switched off and the 600MHz parabola was placed in a horizontal position to prevent wind damage. Thus, under the coordination of M. Dufond, all working instruments were left in such a way that they can be reactivated at any time. The 6-m refurbished dish is ready to receive new receiver electronics. No irreversible damage or failure is expected during a 6 to 12-month interruption. For what concerns the data gap in the 600MHz 50-year long time series, it is unfortunate and detrimental, but as long as it remains short relative to the solar 11-year cycle duration, it does not decrease significantly the value and usefulness of the entire series. Still, all of the above indicates that a final decision for the future of radioastronomy in Humain must be obtained within 6 to 12 months, and that past delays on the evaluation must not be repeated.

D.3.3. Perspective for next years

The future orientation of the radio-astronomy activities at the Humain station will depend on the conclusions, at the level of BELSPO, concerning extra funding, on the base of a long-term science and budget plan to be submitted in early 2006. Normally, an audit should also be organized on request of the Scientific Council.

International activities:

- Study of synergies for future radio instruments in Humain in the context of the CESRA and the International Heliophysical Year.
- Possible technical collaboration with ETH Zurich for the installation of a radio spectrograph (CALLISTO project)

D.3.4. Personnel involved

Science management, site protection: F.Clette
Technical maintenance, instrument operations: J-L Dufond (management), P. Janssens (resident), S.Walkiers.
Data processing: J-L. Dufond, A. Ergen.

D.3.5. Partnerships

List of national and international partners

Dr. K. Tapping (Dominion Radio Astronomical Observatory, Penticton, Ottawa, Canada)
Dr. M. Messerotti (Trieste Solar Radio Observatory, Italy)

Grants used for this research

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Visitors (give only the total number)

1 group (educational)

D.3.6. Publications

Web distribution of daily 600MHz solar flux plots on the SIDC web pages (until 31/7/2005).
Daily-averaged 600MHz background flux listed in the SIDC Sunspot Bulletins (12 issues, solar indices table, p.3) (until 31/7/2005).

D.3.7. Missions

Operational missions: 3
Field missions: 30 (from Jan. to July 2005)

E. Activities in support to institute-wide projects and services

Preparation of the solar chapter of the ROB yearbook 2006

- Computation, edition and verification of the solar ephemeris tables for 2006 (local circumstances for Uccle, geocentric parameters, solar rotations): the careful examination of the results revealed a systematic disagreement of the apparent solar radius versus several other publications. This discrepancy is significant (0.1%) and existed for many years, in the past issues of the Yearbook. It should be elucidated, which can only be done after fully deciphering and re-writing the old existing program (cf. below).
- Full update of the conversion scripts generating the LATeX output.
- Re-writing of the computation programs: the old programs are written for a BASIC compiler that is no more supported. A priority was given to the re-writing of the software into a modern language:

    - The translation to C and FORTRAN language was initiated in 2005, but progressed very slowly due to a lack of staff. This effort allows building on the existing method and will allow the full understanding and documenting of all values published in the past.
    - In a subsequent step, we consider using the standard FORTRAN routines from T.Pauwels (fully up-to-date Earth ephemeris) augmented with a specific solar ephemeris library (Carrington rotations, P, B, L angles), which must be written from scratch.
- In addition to the main publication in the Yearbook, the tables are also sent every year to the Casterman Editions for their publications (via the ROB information Services)
- Regarding the re-writing of the programs in 2006, we will first translate the existing algorithm into a new documented program and then adapt the relevant parts of the current programs (once identified and checked) to combine them with the standard ephemeris routines developed by T. Pauwels for most of the other sections of the yearbook.

Student training

- J.F. Hochedez is co-promotor for the Phd of Samuel Gissot
- 2005/03/24: J.F. Hochedez act as Jury member in S. Gissot's library exam in LLN
- 2005/05/18: : J.F. Hochedez act as Jury member in S. Gissot's exam in LLN
- 2005/03/19: defense of Leen Devalk who J.F. Hochedez had trained in 2004
- D. Berghmans is co-promotor for the Phd of Eva Robbrecht
- D. Berghmans is lector of the Master thesis of Katrien Verheyen
- P. Vanlommel was mentoring Evi Wees, student at 'De Wijnpers', Leuven: practical arrangement with herself and her mentor.
- A. Ben Moussa was supervisor for M. SAY from Institut Superieur Industriel de Bruxelles (ISIB)
- E. Robbrecht was mentor for Inneke d'Hollander, a student of the Higher Nautical School of Antwerp
- F. Clette is "Maître de Conférences" for a course "Le Soleil : structure, activité et impact sur l'environnement terrestre", DEA in Astrophysics and Space Science, University of Liège (Institut d'Astrophysique, J-C Gérard), Academic year 2004-2005.

Public outreach:

Interviews:

- 2005/04/12: JF Hochedez: 1-hour interview on Solar Physics at Radio Campus
- 2005/10/03: JF Hochedez: short interview on eclipses at ROB by Radio Campus
- 2005/06/23: F. Clette: Telephone Interview from New York by Wall Street Journal (S. Power): disturbances of new anti-impact radars in automobiles on radioastronomy.

Public Lectures:

- 2005/10/20: J.F. Hochedez gave a talk at the conference in honour of Delaboudinière
- 2005/11/24: Popularization talk by J.F. Hochedez, Reims
- 2005/09/11: "Het weer in de ruimte", Volksterrenwacht Urania,
- 2005/10/27: Eva Robbrecht gave a general presentation on solar activity for the Service Club Soroptimist International in Sint-Niklaas.
- 2005/11/11: Eva Robbrecht gave a presentation on the sun and space weather in the planetarium MIRA in Grimbergen during the annual meeting of the solar observers' amateur club.

Exhibitions & conferences:

- 2005/06/27: J.F. Hochedez wrote the introduction to EIT for exhibit at the Planetarium

- D. Berghmans was active member in the LOC of the solar physics conference "SPM11: The Dynamic Sun: Challenges for Theory and Observations", Leuven, 2005/09/11-16
- P. Vanlommel made an update of the 'Space for you'-movie and making of poster 'De Zon' in the framework of exposition 175 jaar Belgie.

Visits:

- Guided tours for the general public of the Solar Dome and Space Weather forecast Center during Open Doors, Sept 17, 2005 (P. Vanlommel, E. Robbrecht, F. Clette, D. Berghmans).
- Guided tours at ROB for SPM-11-attendants, Sept 13, 2005 (P. Vanlommel, E. Robbrecht).
- 24/5/2005: F. Clette welcomed a group at Humain from UTAN (UniversitÈ des AinÈs), Namur
- 29/4/2005: F. Clette welcomed a group visit, Liège DEA students (course of M. Arnould)
- 21/.11/2005: F. Clette welcomed a group visit, students of V. Dehant (UCL)
- 17/12/2005: F. Clette welcomed an amateur astronomer group (Lead: P. Dobbelaere): preparation meeting for the March 29, 2006 total solar eclipse.