

# Belgian report to JOSO: 2004-2006

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In 2004-2006, Belgian solar physics research was again largely concentrated in the SIDC (Solar Influences Data analysis Center), i.e. the Solar Physics group of the Royal Observatory of Belgium. In fact, this central role was further reinforced in the course of 2004-2006 by the recruiting of many new post-docs, with a current total staff of 29, of which 14 scientists. However, this growth in manpower resided entirely in the recruiting of contractual scientists (space projects), while the permanent staff was globally declining over the same period. Still, this productive community of young scientists gives to the SIDC a central role for solar physics in Belgium, with also a clear international dimension. This is even reflected internally, as 10 nationalities are represented within the SIDC staff (Belgium, France, UK, Italy, Germany, Russia, Ukraine, Romania, USA, Argentina and soon Netherlands).

## **Solar Influences Data analysis Center (SIDC, Royal Observatory of Belgium)**

The activities were oriented along two main axes:

- Solar coronal research, mainly based on the exploitation of space experiments.
- International operational solar monitoring services and supporting ground-based observations.

Solar eclipse research, which was one of ROB's central research topic of the past decades, has come to an end since 2002, given the strong development of space-related research brought by the successful SIDC participation to the SOHO mission.

More information about the various projects can be found on the SIDC web site (<http://sidc.be>). A list of publications is available at <http://www.sidc.be/publications/index.php>.

## **Solar space research**

The main research topics were:

- Statistical properties and dynamics of small-scale activity (nanoflares) based primarily on wide-field EUV imaging of the corona and transition region. Special attention is given to the global evolution of small-scale dynamics over the solar cycle.
- Detection and analysis of magnetic loop oscillations and propagating disturbances in loops (EUV imaging and spectroscopy).
- Statistical properties of CME's and of their connection with on-disk EUV dimmings and waves.
- Investigation of the statistical relations between CME source properties and the corresponding physical properties of interplanetary disturbances in the heliosphere.
- Determination of the solar differential rotation and proper motion of bright points and other coronal features.

Those fundamental research topics were fed by a major effort undertaken by the SIDC team in terms of solar image processing:

- Feature extraction and tracking by wavelet analysis, segmentation (watershed, etc.) and optical flow methods: this work is developed in close collaboration with external specialists in various mathematical faculties in Belgium and France.
- Automated event detection, including for instance:

- CACTus (Computer Aided CME Detection) algorithm developed for SOHO/LASCO coronagraph images and now implemented for the STEREO mission. (<http://www.sidc.be/CACTus/>)
- NEMO (Novel EIT wave Machine Observing): automated detection and measurements of EIT waves and dimmings. (<http://www.sidc.be/NEMO/>)
- B2Xflare: an automated EUV flare detector (<http://www.sidc.be/B2X/>)

Those various researches also rested on the exploitation of operational space missions, on the participation to upcoming space missions and also on the development of future solar space instruments:

- SOHO (EIT, LASCO): the ROB continued its participation as co-investigator, which started in the early days of the SOHO mission development. This included the extensive exploitation of EIT and LASCO data (full copy of the data archive maintained at ROB) and e.g. the initiation of the EIT "high-cadence synoptic" program that now includes more than 20 campaigns spanning 7 years (<http://www.sidc.be/EIT/#>).
- STEREO (SECCHI, HI): participation to the scientific exploitation and development of near real-time event and feature detection tools to be included in the primary data pipeline (<http://sol.oma.be/SECCHI/>).
- PROBAIL (SWAP, LYRA): the SIDC and the Centre Spatial de Liège (CSL) proposed a suite of two solar instruments for this technology-demonstration microsatellite developed in Belgium for ESA (<http://sidc.be/Proba2/>). The instruments are now in the final steps of their construction, with also a participation from France (Institut d'Optique, IOTA) and from Switzerland (PMOD, Davos), in view of a launch in early 2008 (2-year nominal mission). The payload consists of:
  - SWAP (<http://swap.oma.be/>): wide-field EUV imager using a CMOS APS "intelligent" detector (single monochromatic channel: FeX line) designed to offer a wider field of view than EIT, with off-pointing capability and faster images cadence (1 min). This small imaging instrument was thus optimized for the detection of the elusive EIT waves and off-limb EUV CME's.
  - LYRA (<http://lyra.oma.be/>): array of UV and Ly- $\alpha$  radiometers based on diamond detector technology, offering improved aging properties versus radiation damages and visible-light blindness (improved calibration by absence of rejection filters).

The SIDC is also in charge of the in-flight and ground software. It will carry out the science operations as well as implement and host the primary PROBAIL data archive.

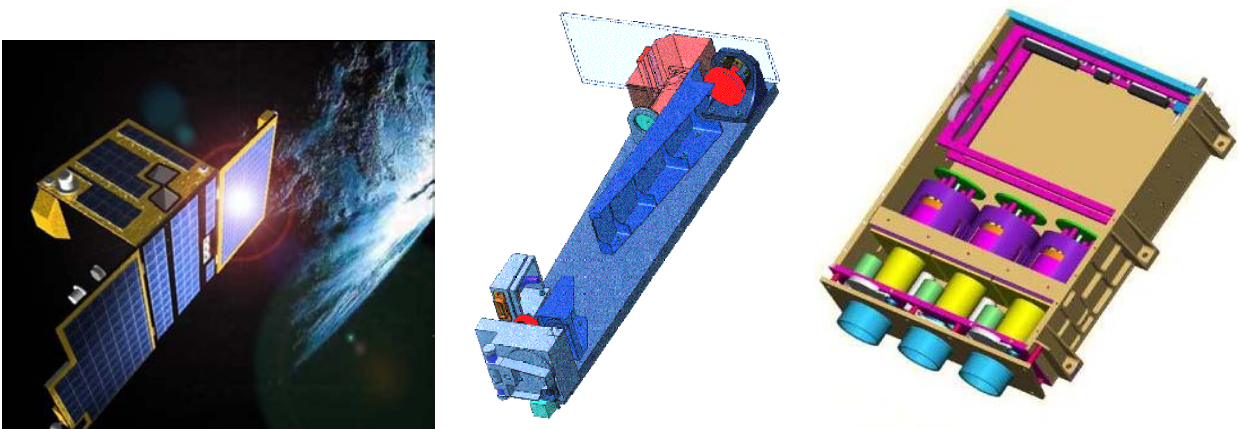


Figure 1: Artist view of the PROBAIL spacecraft and of the instrument structures of SWAP (left) and LYRA (right). SWAP is an off-axis EUV telescope with CMOS APS imager. LYRA is an array of three redundant 4-channel UV radiometers.

- Other future missions currently in preparation:

- Proposal for the wide-field EUV imager (EUI) concept for the Solar Orbiter mission (ESA).
- Participation to the AIA instrument (SDO mission): real-time data processing, data exploitation.
- Participation to the TESIS instrument (CORONAS-Photon): data exploitation

Many international research collaborations were developed over the years, including: NASA Goddard SFC, Naval Research Laboratory, Institut d'Astrophysique Spatiale, Observatoire de Paris-Meudon, Lockheed-Martin SAL, Hvar Observatory, Max-Planck Institute, Kiepenheuer Institute, etc.

### **Operational services**

The core of the SIDC resides in its two operational services (<http://sidc.be>):

- World Data Center of the IAU for the sunspot index (since 1981, i.e. 25 years in 2006)
- Regional Warning Center (Belgium-Europe) of the ISES (International Space Environment services) since 2000.

The WDC, in spite of its very limited staff, continued to compute the international sunspot number based on observations from a worldwide network of 89 stations in 29 countries. Its role is to preserve and extend this unique long-term record of solar activity, which experienced a strong rise of interest from a wide scientific community over the last few years (~100 publications per year referring to this index). Still, some innovations were introduced like a Web-based observing report to make data import more reliable. Another addition is the EISN (Estimated International Sunspot Number), a prompt index derived on a daily basis from a subset of about 15 stations. In 2006, a temporary post-doc contract allowed to develop a preliminary study of the sunspot time series using the concept of non-linear dynamical systems.

The Regional Warning Center (RWC) processes and distributes various solar and geomagnetic data on a daily basis. It also issues activity forecasts and real-time event alerts. In order to provide those services to more than 450 registered users, it makes extensive use of the SIDC participation to various space missions to convert research results into operational tools, like CACTus or NEMO now in routine use for solar monitoring and forecasting. Another development is the Solar Weather Browser, a versatile multi-source solar image browser (<http://www.sidc.be/SWB/>): based on autonomous open-source client software, it allows a seamless navigation through image series at various wavelengths with the inclusion of various graphical overlays.

The SIDC RWC also took part, as the "solar" segment, in the ESA Space Weather Pilot Project. The Pilot Project was a first study for the future development of a user-oriented European-wide infrastructure for operational Sun-Earth interaction monitoring and forecasting.

### **Ground-based solar instruments**

The SIDC runs its own ground-based facilities that are meant primarily for the continuous monitoring of the global solar activity (solar patrol and synoptic observations) in the optical and radio domain. This includes two stations in Belgium. Over many years, both facilities suffered from a lack of permanent staff, but there was a significant degradation over the period 2004-2006, due primarily to the retirement without replacement of several staff members (scientists and technicians). This had severe consequences on the continuation and development of those facilities. Presently, only one permanent scientist is available to take care of all ROB solar instruments.

### *USET, the Uccle Solar Equatorial Table (Brussels):*

Two CCD cameras have been in continuous operation since 2003: a white-light synoptic camera and an H- $\alpha$  system meant for solar flare patrol but mostly used in synoptic mode. The visual telescope for sunspot observations is also still one of the primary reference instruments of the WDC-sunspot network. The images and drawings are all made available in near-real time on the SIDC Web site:

[www.sidc.be/LatestSWData/LatestSWData.php](http://www.sidc.be/LatestSWData/LatestSWData.php) and [www.sidc.be/news/038/welcome.html](http://www.sidc.be/news/038/welcome.html)

The instruments remained largely unchanged over the 2004-2006 period. However, considering the aging of various pieces of equipment, a project was developed in 2006 to seek funding for a modernization of the USET. A funding was finally obtained for 2007 (Belgian National Lottery funding to science research). It will allow upgrading the CCD cameras (2048x2048 pix) and the H- $\alpha$  monochromator (replacement of vintage Lyot filter). It will also allow adding a new channel in the Ca-II-K line for synoptic calibrated observations. This CaII-K telescope will be developed in collaboration with the Observatory of Rome (PSPT/RISE consortium).



Figure 2: The Uccle Solar Equatorial Table with its 3 solar patrol telescopes and an outside view of the solar dome.

### *The Humain radioastronomy station (Marche-en-Famenne, S-E Belgium):*

Due to the reduced and insufficient technical staff, the radio observations were already limited to the 600MHz integrated flux by 2004. The big 408MHz radioheliograph had indeed been turned off in 2002, but the 600Mhz series of measurements was continued also because of its unique importance (one of the longest solar series, started in 1955). A modernization project (HUMSOLAR) developing an entirely new concept of real-time radio burst monitoring instruments supporting the SIDC services was prepared in order to regain some funding.. However, the team was further reduced to one unit in July 2005, making it impossible to continue the observations. All radio instruments have been turned off since then, leading to an unprecedented break in the 600MHz radiometric series.

Still, two recent developments (2006) may lead to new prospects for a revival:

- The inclusion of new radio instruments and supporting staff in a "Center of Excellence for Solar-Terrestrial Physics". This Belgian trans-institute infrastructure was promoted by

the Belgian Ministry of Science Policy and was approved by the Government in late 2006. However, its actual implementation may have to wait until late 2007.

- Potential collaboration with the ETH Zurich for the installation of one or multiple CALLISTO radio spectrographs on the Humain parabolas. A survey of the spectrum at the Humain station was carried out in May 2006 with support from the ETH and showed the good quality of the site for spectrography in the decimetric range. The existing Humain buildings and 50 antennas (4m and 6m parabolas) thus offer a huge potential for establishing new modern solar radiotelescopes for just a fraction of the full cost needed to build such a facility.



Figure 3: Panoramic view of the Humain radioastronomy station showing the 48 4m antenna array of the 408MHz radioheliograph (no more in operation) as well as one of the auxiliary 6m parabolas (left side of the image). Most of these parabolas are in working order and can be refurbished with new state-of-the-art receivers.

Other international collaborations have been initiated around the Humain modernization with the Observatory of Trieste and the Dominion Radioastronomy Observatory (Penticton, Ottawa).

### **Center for Plasma Astrophysics (CPA, Katholieke Universiteit Leuven)**

The CPA focuses on plasma theory and applies it to various domains. One of them is solar physics (<http://wis.kuleuven.be/cpa/index.php>), with in particular:

- MHD models of coronal loops
- Heating mechanisms: wave resonant dissipation and phase mixing
- Interplanetary CME modeling: shock propagation

Over the period 2004-2006, significant progresses were made in the simulation of the propagation of CME disturbances across the heliosphere, using solar observations as boundary conditions at the base of the corona. Such physical models, developed in collaboration with the SIDC scientists, should lead on the long term to operational forecast methods of Earth-directed transients. Further progress is expected from the joint participation of CPA and SIDC to the STEREO mission.

### **Solar research by individual Belgian scientists**

- Dr. N.Grevesse (retired; Institut d'Astrophysique, Univ. De Liège): solar spectroscopy based on ground-based and space-based infrared solar spectra.
- Prof. D.Callebaut (retired; Universitaire Instelling Antwerpen): solar magnetism and dynamo theory.