Assessment Information

CoreTrustSeal Requirements 2017–2019

Repository:	WDC - Sunspot Index and Long-term Solar Observations (SILSO)
Website:	http://www.sidc.be/silso
Certification Date:	21 June 2019
This repository is owned by:	**Solar Influences Data analysis Center - Royal Observatory of Belgium**

Core Trustworthy Data Repository Requirements

BACKGROUND INFORMATION

Context

R0. Please provide context for your repository.

Repository Type.

Domain or subject-based repository

Reviewer 1:

Accept

Reviewer 2:

Accept

Comments

WDC-SILSO is the unique repository for the long-term solar sunspot activity record, set up by several scientific unions: International Astronomical Union (IAU), International Union of Geodesy and Geophysics (IUGG) and the International Union for Radio Sciences (URSI).

Reviewer 1:

Accept

Reviewer 2:

Accept

Brief Description of the Repository's Designated Community.

- Solar Physics researchers

- Researchers from other disciplines: Earth climate, Aeronomy (ionosphere, magnetosphere), Astrophysics

- Public and private organizations (space agencies, aerospace industry, telecommunication, electrical power distribution, pipeline operators, finance, etc.)

- General public (education on solar activity), amateur astronomers, radio amateurs

Reviewer 1:

Accept

Reviewer 2:

Accept

Level of Curation Performed.

D. Data-level curation – as in C above; but with additional editing of deposited data for accuracy

Reviewer 1:

Accept

Reviewer 2:

Accept

Comments

Three main curation levels:

- level B: Collection of raw sunspot data from a worldwide network of stations, with quality control (raw data stored in a database)

- level C: Statistical processing of the raw data to produce a global standard-index time series (international sunspot number)

- level D: Re-calibration of the series by recovering new historical data and implementing new methods, based on research work by the WDC-SILSO scientists and partner scientists.

In addition:

- based on the primary index series above, production of mid-term predictions of the index (3 different methods)

Reviewer 1:

Accept

Reviewer 2:

Accept

Outsource Partners. If applicable, please list them.

Royal Observatory of Belgium (ROB): hosting institution, which provides all material resources for WDC-SILSO:

- Manpower: ROB staff members working part-time to run the WDC (and associated office space)

- Equipment: PCs used partly for the WDC tasks

- Global facilities: central data backup system, central computation and Web servers, high-capacity Internet access with site-wide network security system. Those systems are maintained by a dedicated and qualified IT staff (but no formal standard evaluation).

The WDC-SILSO does not own any material resources outside the allocation of a small part of the above existing resources of the ROB. The hosting of the WDC within ROB, and the associated access to outsourced ROB facilities is based on an agreement with the ROB director (formalized in 2012, through the letter of Agreement with the WDS then co-signed by the ROB Director).

Reviewer 1:

Accept

Reviewer 2:

Accept

Other Relevant Information.

The sunspot number produced and preserved by our WDC-SILSO is one of the few long-term indices of solar activity and the only one available before the early-20th century, spanning the past four centuries. Therefore, it is used in a wide range of applications outside solar physics itself, as many processes in the Earth environment are influenced by solar activity. As central repository, the WDC-SILSO (http://www.sidc.be/silso) has a unique role worldwide to maintain this central solar data set. More than 100 research publications use the sunspot number as input data each year, only in the domain of solar physics. Next to science research,

this solar activity index also includes direct applications in the society and economy. Moreover, sunspots are part of public culture and are thus a primary link used to communicate about solar activity with all citizens. Our sunspot data and graphics are thus used in many non-scientific publications and Web sites. A Google search for "sunspot number" typically leads to more than 1,500,000 hits, also illustrating the wide impact of this data set.

All this explains the extreme diversity of our user community.

Reviewer 1:

Accept

Reviewer 2:

Accept

ORGANIZATIONAL INFRASTRUCTURE

I. Mission/Scope

Compliance Level: 3

R1. The repository has an explicit mission to provide access to and preserve data in its domain.

The WDC-SILSO is a sub-entity of the Solar Influences Data Analysis Center (SIDC) also known as the Solar Physics and Space Weather department of the Royal Observatory of Belgium (ROB). An organigram of the structure is represented on http://www.sidc.be/silso/about.

The mission of WDC-SILSO is to preserve the long-term multi-century sunspot number time series and to produce new numbers for extending this series over decades (multiple 11-year solar activity cycles), by processing raw sunspot observations from a worldwide network. The resulting data series is made freely available (licence CC-BY-NC) to all users via several channels (Website, mailing service, monthly Bulletins, quarterly bulletins).

In addition to those primary duties, complementary data products are also developed, based on the primary time series (predictions, graphics, quick-look estimated sunspot number, image-based sunspot indices, sunspot catalogs) in response to new user needs and scientific progresses.

See the SILSO Web site (http://www.sidc.be/silso) "Data" and "Products" sections. See article by Clette et al. 2007 (http://www.sidc.be/silso/IMAGES/about/Clette_JASR8745.pdf).

Those objectives were historically inherited from the original curators of the sunspot number at the Zurich Observatory, where the sunspot number index was created in 1859 by Rudolph Wolf. After the closing of the Zurich Observatory in 1980, the World Data Centre was transferred to the ROB in Brussels following official resolutions by IAU and URSI in 1982 (Cf. Article Berghmans et al. 2006, and documents ResolutionU21_URSI_1982.pdf and TransferProposal_Zurich_Brussels.pdf at http://www.sidc.be/silso/about). Until recently, these short resolutions were the only existing formal documents defining the mission of the WDC and settling the scientific endorsement by scientific unions. At the distant epoch when the WDC was established in Brussels, the transfer of the know-how and duties largely occurred by personal contacts and mutual visits between the Brussels and Zurich teams. The ROB was chosen because of its expertise in sunspot observations and the fact that its Uccle solar station was one of the main and longest-contributing station in the international sunspot monitoring network.

Today, we have official resolutions from the Sun and Heliosphere division of the IAU, from URSI as well as IUGG through IAGA. They form a supervising committee for the data and data workflow from the WDC-SILSO.

Regarding organizational approval, it entirely rests on the ROB, our hosting institution, and its director (currently Ronald Van der Linden) who co-signed in September 2012 a Letter of Agreement with ICSU (see Annex R1).

Reviewer 1:

Accept

Reviewer 2:

It is necessary (and highly beneficial) to make the enclosed documents available on the WDC-SILSO website. In particular, the 'About' page should explain the mission of WDC-SILSO and the mandate from IAU, IUGG, and URSI. The current About page with the diagram is a good first step, but really needs more explanation for the users (http://www.sidc.be/silso/about)

II. Licenses

Compliance Level: 4

R2. The repository maintains all applicable licenses covering data access and use and monitors compliance.

The sunspot number data are distributed under a CC-BY-NC license. We request proper citation of the data source, as explicitly indicated in our Web pages (http://www.sidc.be/silso/citations).

However, we don't have the material means to monitor compliance of the numerous scientific and non-scientific users (NB: We occasionally notice publications or websites featuring our data without proper citation: we usually send a reminder to the authors.).

We would have liked to implement an identification step (e-mail address requested) before a user can fetch data, in order to have better control on proper citation. However, we have concerns that requiring more action from the user before accessing the data may lower the rate of use, when our goal is to maximize data use. To keep track of the usage of the SILSO data and monitor our website, we use google statistics, which are very helpful and detailed.

The ROB itself has also defined conditions of uses for data produced in the ROB context, and has defined a specific section for WDC-SILSO products:

http://www.astro.oma.be/en/information/data-policy/

At the ROB level, there is no systematic monitoring either and no explicit measures in case of non-compliance.

Next to the data series that we produce, the raw sunspot data coming for all past and current stations of the SILSO are stored in a private database. Those data were never publicly distributed in the past, back to the origins in 1859. Still, on request from scientific users (typically by e-mail), we can provide such data (subset selection). This happens only for specialized research, e.g. for the re-calibrations of past sunspot data, in the context of a bilateral scientific collaboration. The SILSO scientist is then typically a co-author of the resulting publication.

The data provided by the observers is not creative, thus not subject to copyright. Note that observers enter their data willingly through an interface dedicated to the WDC-SILSO network. Although this should act as a tacit agreement, the active observers will also give us the right to use their data through the above-mentioned interface during 2019.

Reviewer 1:

It is difficult to find mention of the chosen licence on the page: http://www.sidc.be/silso/citations

Reviewer 2:

Accept

III. Continuity of access

Compliance Level: 4

R3. The repository has a continuity plan to ensure ongoing access to and preservation of its holdings.

So far, the strategy for long-term preservation of the data largely rested on the specific characteristics of our sunspot data set: the small volume of the data. The main data series with metadata holds in a few Mbytes (uncompressed ASCII text files) and even the database of all raw data (600,000 measurements) can fit in a 1 GByte USB key.

Technically, this allows to keep multiple copies on various independent computers and storage disks for a minimal cost. Data distribution can be done through a "guest" Web page on an existing Web server, like it is the case now (ROB Web server). Therefore, the data holdings are not exposed to the shutdown of a large storage facility, e.g. because of ceasing funding.

Instead, the main risk is associated with the minimal size of the team dedicated to the WDC-SILSO (see section R5 “Organizational Infrastructure” below): only one permanent scientist, helped by a post-doc researcher (short-term project funding) and a part-time Web-manager. Therefore, there is limited competent backup to ensure continuity of the services. This is less than ideal regarding the transmission of know-how to ensure a smooth transmission or relocation in case the WDC-director cannot continue (e.g. retirement). Historically, the WDC sunspot always relied on a small team, but until 2002, there were always at least two permanent scientists who could interchangeably care for the WDC operations and data preservation. Together with the small size of the data set, this guaranteed that the continuity could be reasonably maintained. This has not been the case anymore over recent years.

Since 2011, we started actions beyond the ROB to plan for continuity: (1) we developed a network of partners as possible relocation candidates; (2) we looked for possible external permanent storage on a general-purpose open-access repository; and (3) we are documenting the past and present production methods as well as the identified defects in the sunspot number. This is described in more details in the Preservation Plan document attached to this application. However, because of the small size of our team and the considerable achievements of the last years, this can only be carried out on a best-effort basis.

Reviewer 1:

Accept

Reviewer 2:

Accept

IV. Confidentiality/Ethics

Compliance Level: 4

R4. The repository ensures, to the extent possible, that data are created, curated, accessed, and used in compliance with disciplinary and ethical norms.

Our sunspot data don't involve ethical issues, with one possible exception: some personal metadata about the observing stations.

Note however that:

- Such metadata, just like the raw observations at the base of the compiled sunspot index, are not part of our publicly accessible data. They are only provided on request in the framework of direct bilateral scientific collaborations (cf. above). Any explicit use of raw observations from specific observers in science publications includes the citation of the station Identification (only observatory or observer name).
- The stored station information is rather limited and mostly technical: geographical coordinates, altitude, type of telescope, name and street address, e-mail address (for SILSO correspondence). For scientific use, the latter are not necessary and thus not communicated, as anyway, we use two-letter station codes to sort data in our data base.

By the nature of our activity, we don't need to store or share any other sensitive personal data.

Regarding the raw numbers themselves (raw data ownership), since the origins in 1849, they have always been contributed on a voluntary basis. Two-thirds of the stations are individual amateur astronomers. There was always an implicit agreement that those data were "offered for science" without any notion of private ownership. Therefore, when e.g. recruiting new observers, we don't include any commitment to keep their contributed observations private (So far, this was never requested by an observer). Still, currently, we don't distribute openly those raw data, although we have now the technical capability (database). The data input interface used by observers (password-protected Web form. See http://www.sidc.be/WOLF) allows them only to view their own data. As a return for their commitment, they also get back monthly and yearly statistics about the quality of their raw observations versus the final global index.

The owner of the historical datasets is officially the ROB and although we have an implicit agreement with the current observers, we will formalize it in the very near future through our web interface with our network (sidce.be/WOLF). This will make the WDC-SILSO database GDPR compliant. An email will also be sent to all observers in 2019 to confirm their agreement for the use of their data.

Reviewer 1:

It is a point of vigilance to ensure that compliance with GDPR is officially implemented.

Reviewer 2:

Accept

V. Organizational infrastructure

Compliance Level: 4

R5. The repository has adequate funding and sufficient numbers of qualified staff managed through a clear system of governance to effectively carry out the mission.

Since the WDC-SILSO was transferred to the Royal Observatory of Belgium, it has always functioned entirely via the internal ROB resources put at its disposal by the Director and by the head of the Solar Physics Department. Except for an initial personal letter of agreement between the first Director of the WDC (Dr. A. Koeckelenbergh) and the ROB Director (Prof. P. Melchior) dating back from 1981, the support of the ROB to our WDC has always been based on a tacit agreement of principle. A more formal commitment from ROB is described in the letter of agreement co-signed with the current ROB Director in 2012 (see Annex R1). The technical infrastructure associated to the WDC-SILSO is described in http://www.sidc.be/silso/IMAGES/about/Technical_Infra_ROB_SILSO.pdf.

The letter of Agreement (LOA) from 2012 between the WDC-SILSO and ICSU defines the role of the WDC-SILSO and defines the responsibility of ROB towards WDC-SILSO (point 5.). On a technical level the provision for this responsibility is further detailed in the "Technical Infrastructure" document (http://www.sidc.be/silso/IMAGES/about/Technical_Infra_ROB_SILSO.pdf). All of this could indeed be split and regrouped in a stand-alone MOU between ROB and the WDC-SILSO but since the WDC-SILSO is a section of the ROB, we feel it is more transparent to specify the agreement and understanding with respect to the external partner ICSU as is done in the LOA.

Hosting institution

The hosting institution (ROB) is a governmental research institution founded in 1830 (staff ~150 people, mostly scientists) and active in the fields of astrophysics, celestial mechanics, geophysics, geodesy and solar physics. Together with 12 other federal institutions, it is managed by the Belgian Science Policy Office (http://www.astro.oma.be/en).

Competences in the ROB Solar Physics Department

In the domain of Solar Physics, the Solar Physics department, now called "Solar Influences Data analysis Centre, SIDC; http://www.sidc.be) has an expertise that started in 1939 with the creation and continuous operations of the Uccle solar station (USET: Uccle Solar Equatorial table). This facility has been continuously modernized over the past 20 years and is still in operation, providing now digital full-disk synoptic images of the Sun in near-real time (http://www.sidc.be/uset). The Solar Physics department is also involved in radioastronomy and in multiple solar space projects of ESA and NASA as Co-Investigator or Principal Investigator (SOHO, STEREO, SDO, PROBA2 and 3, Solar Orbiter). The current staff amounts to ~45 collaborators, mostly contractual scientists and post-Docs hired in the framework of short-duration space

projects. Nowadays, the Solar Department suffers from a strong imbalance, with only two permanent scientists (2.5% of total), and very limited and declining support staff (programmers, electronics engineer, administration).

Available manpower

As a consequence, permanent operational services like the WDC-SILSO or the USET solar station, must rely on limited staff, namely:

- 1 permanent senior scientist (F. Clette, permanent): 60% for WDC-SILSO (including 15% research and 40%operations), 40% for the USET station.
- 1 post-Doc scientists (L. Lefèvre, contractual): 25% for WDC-SILSO (of which 20% research and 5% operations), 75% dedicated to projects related to sunspot science that partly cover the WDC-SILSO needs.
- 1 operator and Webmaster (O. Lemaître, permanent): 30% for WDC-SILSO (Web site and database maintenance), 60% for the USET station (Web site, observations, digitization and catalogues)
- 1 USET operator (O. Boulvin, permanent)
- 1 USET Post-Doc scientist (S. Bechet, contractual): 5% (help for GIT repositories), 95% for USET solar telescopes (technical development, image processing and research)

Beyond those dedicated resources, in order to fulfil its missions, the WDC largely depends on the ROB institutional common resources:

- Data and Web servers, maintained by the ROB central IT service, supported by a multi-annual budget for IT investments in all federal institutions.
- Equipment purchase (personal computers, travel budgets, consumables) supported financially by a federal Solar-Terrestrial centre of Excellence (STCE; http://www.stce.be) that is networking three federal institutes with expertise in solar-terrestrial physics. This STCE programmatic framework was stable over the past 10 years, since its creation, and is expected to continue over coming years, although it is more exposed to changes in governmental policies than institutions like the ROB itself.

Overall, the available resources are sufficient to maintain continuous routine operations of the WDC, but not to ensure continuous development of the data centre, in order to remain state-of-the-art and to conduct research leading to improvements of the scientific data products.

Still, over the past 6 years, our small team (F. Clette, L. Lefèvre) produced breakthroughs in the understanding and in the quality of the sunspot number series, while simultaneously undertaking an unprecedented modernization of all the data production software (documentation, porting codes from heritage-Fortran to Python, graphical products, porting data from ASCII files to databases). Multiple corresponding peer-reviewed publications include a book chapter (domain review; https://doi.org/10.1007/s11214-014-0074-2) and a special issue of Solar Physics, the main peer-reviewed publication in the field: Solar Physics, Volume

291, Issue 9-10, November 2016, "Sunspot Number Recalibration", Guest Editors: F. Clette, E.W. Cliver, L. Lefèvre, J.M. Vaquero, and L. Svalgaard ISSN: 0038-0938 (Print) 1573-093X (Online) (https://link.springer.com/journal/11207/291/9/page/1). However, this successful effort implied working over week-ends and holidays, putting a heavy load in the team (work exhaustion problems). This is thus not a viable way to keep the WDC-SILSO state-of-the-art in the discipline, and it cannot be continued on the long term.

WDC staff qualifications

As mentioned above, the WDC-SILSO scientists benefit from an international recognition, largely based on the advances accomplished by the current team since it took over the data centre in 2011. In addition, as senior scientist, F. Clette has accumulated over his career a broad expertise in various domains of solar physics, from the ground and in space (See attached CV). In particular, he has contributed in various ways to the WDC activities over the past 30 years by providing help to the previous Directors of the WDC (running procedures, developing software tools) and has been managing the USET solar station for the last 15 years. This allowed him to acquire an intimate knowledge of the processes and methods, which helped to establish a clear modernization plan when he took over as Director in 2011. Next to his WDC and research activities, F. Clette is also:

- Maître de Conférence : course on Solar Physics for the Master in Astrophysics and Space Science of the University of Liège
- Co-Chair of the Inter-Division Working Group "Coordination of Solar Synoptic Observations" at the International Astronomical Union (IAU)
- Member of several Commissions at the Royal Academy of Sciences of Belgium.
- Member of IAU, URSI, COSPAR, AGU

L. Lefèvre brings a background in astrophysics combined with advanced data mining techniques developed during her PhD thesis devoted to photometric series of stellar populations monitored by the Corot spacecraft.

S. Bechet, recently recruited for the USET solar station, provides occasional help regarding GIT version tracking systems and on-line software and data repositories, which she applied in her previous research position dedicated to high-energy astro-particles (IceCube).

[See also CVs in Annex R5.]

Thanks to personal travel budgets for individual scientists (mainly from STCE), the WDC staff can attend international meetings in the framework of their research, and can thus take part in international science exchanges and communication. However, this travelling ability is mainly limited by the availability of the WDC staff, as any absence puts the base data curation at risk in the absence of fully trained backup staff when a SILSO scientist is absent. Moreover, no budget is available for technical trainings relevant to the data

curation activities of the WDC. Therefore, progress (new programming languages, new data tools) was mostly achieved by voluntary self- learning, and was thus slower while increasing the workload.

Summary of operational tasks

- Monthly production of provisional sunspot number (data import and quality control, verification of results, archiving and verification of proper operation of processing software, graphics production and mass e-mail sending, production of e-mail messages and the monthly Sunspot Bulletin). We have more than 500 registered users for our bulletins.
- Quarterly production of definitive sunspot numbers (tasks similar to provisional processing but for three months, with final verification of consistency between provisional and final processing results)
- Daily maintenance of database input (support to contributing stations, inclusion and initial briefing of new stations, monitoring of database server and database integrity)
- Daily maintenance of the SILSO Website (verification of proper operation of Web server, news items, adaptations and re-design to accommodate new products, new data versions, new documentation, new graphics)
- Daily communication (e-mail):
- Data and information requests from users worldwide, from simple explanations for the general public to detailed scientific answers to focused queries from researchers
- Contacts with stations of the SILSO Worldwide observing network for all coordination and support matters.
- Ongoing modernization of the processing and archiving software: porting of heritage software to new software tools (verification, correction, documentation and re-coding of programs; development and populating a global observation database (currently more than 500,000 individual observations), redefinition and rationalization of archiving data flows, introduction and improvement of derived data products (graphics, hemispheric sunspot numbers, real-time estimated sunspot number EISN, three mid-term prediction methods).

Summary of research tasks

- Global analysis of all observers in the SILSO database (285 stations) to study observation error properties and behaviour of individual observers (error determination, improvement of quality control)
- Diagnostic and determination of inhomogeneities in the sunspot number series over past decades and centuries. This task includes:
    - internal research (homogeneity of data produced in Brussels over the last 35 years, issues in the former Zurich data production)
    - internal data recovery work (currently bulk encoding of all past raw observations collected by the Zurich Observatory over 130 years (1849-1880) in paper archives)

- also, the initiation and coordination of a community-wide research effort, centred on a series of Sunspot Number Workshops. F. Clette, together with US colleagues, leads this joint work (~40 participants, no available funding) that already led to the production of the first-ever revision of the sunspot number series and now continues to work on future versions. Regarding those SN workshops see: http://ssnworkshop.wikia.com/wiki/Home and http://www.issibern.ch/teams/sunspotnoser/

In 2017-2019, this coordination involves the creation of a common on-line work platform (shared workspace for software and data on GIThub, Jupyter, Zenodo)
(involvement of all international experts in this science topic, i.e. a more participative version of a Scientific Committee that would be set up by the overarching scientific unions, IAU or URSI)

- Evaluation, improvement and extension of three mid-term sunspot number prediction methods (McNish & Lincoln, taken over from NOAA, Boulder, USA, Standard-Curves method, and Combined method) including Kalman-filter optimization (response to growing demands for multi-year predictions, in particular from the industry). See: http://www.sidc.be/silso/forecasts

Reviewer 1:

The governance system is not entirely clear.

Reviewer 2:

The limitations identified by the repository should however be addressed insofar as possible to ensure continuous and improved operations in the future.

VI. Expert guidance

Compliance Level: 4

R6. The repository adopts mechanism(s) to secure ongoing expert guidance and feedback (either in-house, or external, including scientific guidance, if relevant).

Although no official Scientific Committee has been set up yet by the supervising scientific unions, we now have resolutions from IAU, IAGA and URSI. We developed a very close involvement with essentially all scientific experts currently working on the specific topic of long-term indices of solar activity, either the sunspot number itself or also other solar indices or geomagnetic indices for the more recent past (180 years or less) and also cosmogenic radionuclides. By involving those scientists in a joint investigation of past data and calculations leading to the sunspot number series, we ensure that the highest expertise is included in the current data and that the present and future data set addresses the needs of current and future solar research.

As mentioned in the previous section, this joint international work is articulated around a series of Sunspot Number Workshops. Under the impetus of the Version 2.0 achievement in 2015, it is now continued in a more integrated form in view of upcoming ISSI workshops in 2018-2019: work sub-divided in topical working groups, common on-line "sandbox" platform for a fully transparent exchange of data and software about data and methods brought by each contributor. This is a fully innovative working framework for the sunspot number production and even much more broadly over many science disciplines.

For more information about those SN workshops, see: http://ssnworkshop.wikia.com/wiki/Home and http://www.issibern.ch/teams/sunspotnoser/

As co-chair of the IAU Inter-Division Working Group on "Coordination of solar synoptic observations", F. Clette is now promoting a more formal endorsement by IAU of this coordinated expert participation in the sunspot number upgrades. This could be implemented over coming years depending on the responsiveness of IAU authorities. We attach a letter from the IAU Division E to show the endorsement of the IAU.

Reviewer 1:

Resolutions from international organizations saying WDC-SILSO is important and valuable do not necessarily guarantee that the adopted mechanisms of the data repository correspond to the state-of-art.

Reviewer 2:

Accept

DIGITAL OBJECT MANAGEMENT

VII. Data integrity and authenticity

Compliance Level: 3

R7. The repository guarantees the integrity and authenticity of the data.

In the case of SILSO, two main types of data must be distinguished, and involve different managements:

1) Raw input data from observers:

Those data are directly typed-in by the observers themselves in our WOLF input interface (http://www.sidc.be/WOLF). This password-protected interface has a direct error feedback programmed in PHP: any inconsistent or incomplete data triggers a pop-up message forcing the station to check and correct the wrong entry. Each station has only access to its own data and cannot alter any data from other stations. In most cases, after data entry, the stations never modify their previous observations. Anyway, on a yearly basis, when all definitive sunspot numbers are computed for the past year (April 1st), the access to the corresponding table in the database is terminated (table renamed) and data can only be added to the current active year via the Wolf interface.

Those data are directly written into a MySQL database, where each station is uniquely identified (registration required) and where each data entry has a creation and modification time stamp. For each station different metadata are kept, including the geographical location and address of each station. This information is provided by the station at the time of its inclusion in the network, and only modified if our WDC is notified of a change by the station. The metadata only include the station ID, time and day of the observation and sky quality.

The system uses standard programming and database tools (html, PHP, MySQL). Regarding data format, as this database has no other equivalent (no other official sunspot number repository in the world), there is no standard format specification. In a way, WDC-SILSO is in the position of defining the disciplinary standard for long-term solar data series.

Note also that so far, those raw data are not publicly accessible. Therefore, users don't have access to those data and thus don't have the ability to change them.

2) The output product: sunspot number time series

Only two possible actions can be applied to the master time series:

- A new month is appended to the series (monthly provisional calculation). Those provisional values are marked in the ASCII file and database.

- The last three months are updated on a quarterly basis, replacing provisional values by definitive values. (NB: the provisional values have been systematically archived separately only since 1992). The definitive values are marked in the archive file and the main database.

The existing routines include tests that prevent any action on data marked as definitive. As double security, in case of program malfunction, past versions of all archives are saved on different computers (backup servers, snapshots of virtual machines). Files placed on our Web server for access by external users are only copies of the original files, stored on the main servers of the ROB (site-wide firewall protection)

Note that those modification restrictions have now been hard-wired in most of the current modernized software, where our predecessors essentially applied them in purely manual procedures (the only protections were backup files). Moreover, as except for the monthly appending of new data, the early part of the series was never reworked, data older than the last three months were normally never manipulated. As a consequence, except for very basic manuals describing the actions to execute on a monthly basis, no documentation was ever produced by our predecessors (In the past mindset, know-how transmission was based on direct personal training of the few people involved in the data manipulation).

Therefore, we had to start from scratch and we are now rebuilding the whole data flow, while documenting and porting the old software. As this modernization is still ongoing (limited staff!) and the data flow is still evolving, the current integrity processes are unfortunately not documented through formal documents yet. When the migration to new programs will be completed (2019), this could even lead to a scientific article, next to internal reference manuals, as no earlier scientific article from either the Zurich Observatory or the ROB described in detail the past methods and practices, on which the current production is based. Over the past five years, we thus switched to a new mindset regarding data integrity but we need time to fully implement it.

<u>Version tracking</u>

Until June 2015, the definitive part of the sunspot number was never retouched. Only one version existed. Following the first ever end-to-end recalibration campaign started in 2011 (see other sections), the first new version of the series was published, SN V2.0.

As a first step in version tracking, the two existing versions have now been stored in distinct files, with all file names containing the version number and a separate table in our database. By construction, since July 2015, all our processing programs can only access the new Version 2.0. Version 1.0 is not extended anymore. The frozen file and DB table are stored separately in read-only form. Regarding data distribution, we have kept Version 1.0 accessible for reference on a dedicated "Past versions" section of the SILSO Website. This old version and the changes leading to version 2.0 are fully documented in Info items, which include links to scientific publications describing the corrections brought to the series.

As similar but parallel series, the sunspot group number series was simultaneously re-calibrated but so far, it was only accessible as a frozen original copy on the NOAA, Boulder Web site (NGDC/NCIE). We thus decided to also host this series and its successive versions in a dedicated "Group number" section of the SILSO Website, although this is not a primary product of WDC-SILSO.

As a new revision of the sunspot number is already in preparation (release in 2019), this versioning system will be further improved. Next to the documentation of the successive versions in the SILSO Website itself, all versions will be placed on the Zenodo platform (or equivalent), which will also allow to attach a DOI to each new version. This is a work in progress, for a data series that was never revised over more than 150 years …

The technical aspects of the data management are described in the following Technical Infrastructure document: http://www.sidc.be/silso/IMAGES/about/Technical_Infra_ROB_SILSO.pdf.

Reviewer 1:

Accept

Reviewer 2:

Additional evidence of progress to ensure authenticity and integrity and documenting procedures will be required by the next round of review. The repository should particularly implement automated fixity checks (e.g., checksums) and implement audit trails.

VIII. Appraisal

Compliance Level: 4

R8. The repository accepts data and metadata based on defined criteria to ensure relevance and understandability for data users.

As data are directly typed into our Web-based user interface (http://www.sidc.be/WOLF) , we don't have data input format issues anymore (years ago, data were sent as text by post, fax and e-mail). Data are directly fed into the database in a mechanical way (data tagged with the station ID of the user who logged in).

As explained in the previous section, any data inconsistency is immediately indicated by a pop-up in real time, indicating the kind of problem and inviting the station to check and re-enter a correct value. The issues to be fixed are well-defined as the input data are straight sunspot counts (a few integer values). Any anomalous observation detected during the main statistical derivation of the sunspot number is reported to the station be e-mail. They can then check and enter replace directly the value in the Web interface. No intermediate manipulation is needed.

On a yearly basis, the average scaling coefficient is calculated for all active stations, together with the dispersion of daily values. Those data are made available directly to the stations via the same Web-based interface. If any statistically significant drift in the station scale or an excessive dispersion is found systematically for a station, we inquire about the reason of the anomaly. If the station does not improve to stay within the quality limits, it is excluded from the calculations.

All corrective actions involve direct e-mail contacts with individual stations. The quality and dedication requirements are specified when a station applies to join the network. Stations/observers are thus aware of the requirements and the possibility that they are excluded. Over the 35-year history of the WDC at the ROB, there was never any conflict or misunderstood about the expected role of stations. One must keep in mind that all observers are contributing voluntarily and are motivated to make their best efforts. In fact, the production of the sunspot number may be one of the earliest version of scientific data crowdsourcing, well before Internet.

Reviewer 1:

Accept

Reviewer 2:

Accept

IX. Documented storage procedures

Compliance Level: 3

R9. The repository applies documented processes and procedures in managing archival storage of the data.

As mentioned in a previous section, the volume of data (input and output) managed by WDC-SILSO is rather limited compared to current storage capacities. In addition, our data storage rests primarily on the general IT infrastructure of the ROB (central servers, backup services, network security). Our data safety policy thus largely overlaps the general ROB strategy.

The primary files are stored on a virtual machine running the calculation software, while the MySQL database is running on another virtual machine, which is a central server for all databases of the Solar Physics Department (including e.g. databases of space experiments). Snapshots of all ROB virtual machines (and thus data, documentation and software therein) are backed up as part of a global backup system of the ROB every night. Those global backups (defined at a global ROB level) are done following a strategy, which is not publicly documented. It roughly consists in nested cadences: daily backups are kept for one month, a weekly backup is kept for several years, and monthly backups are kept indefinitely. Past backups can be restored on request to the ROB IT service.

In addition, given the small size of the data, copies of the primary files and output files (master sunspot number series) are saved on the personal PCs of the WDC staff members. Over recent months, an internal NextCloud server has been installed at the ROB, providing another convenient non-personal shared storage. Beyond those multiple internal copies, many more copies of the master sunspot number series are stored by our many users. This makes a complete loss of the mains series almost impossible.

Still, in the framework of the ongoing recalibration process, which will bring periodic releases of new versions over coming years, we are preparing the storage of our primary data sets on Zenodo-like repository, thus bringing guaranteed storage for at least the next 25 years (according to Zenodo for example), independently of the future history of SILSO at the ROB. As mentioned in other sections, it will also allow version tracking and DOI labelling.

The technical aspects of the data storage are described in this Technical Infrastructure document: http://www.sidc.be/silso/IMAGES/about/Technical_Infra_ROB_SILSO.pdf.

Reviewer 1:

WDC-SILSO would benefit from developing longer term internal documentation.

Reviewer 2:

The strategy is not fully documented and needs improvement, for example, about checks to ensure consistency across archival copies.

X. Preservation plan

Compliance Level: 3

R10. The repository assumes responsibility for long-term preservation and manages this function in a planned and documented way.

WDC-SILSO has defined a basic a Preservation Plan available at http://www.sidc.be/silso/IMAGES/about/SILSOPreservationPlan_final.pdf

Reviewer 1:

Again, WDC-SILSO would benefit from developing longer term internal documentation.

Reviewer 2:

The basic preservation plan provided should be made publicly available on the WDS-SILSO website and improved over time.

XI. Data quality

Compliance Level: 4

R11. The repository has appropriate expertise to address technical data and metadata quality and ensures that sufficient information is available for end users to make quality-related evaluations.

As explained in previous sections, our data quality policy rests on:

- Direct quality assessment of the input data when entered in our Web-based data input interface (automated)
- Overall statistical tests and filtering of the data included in the main monthly calculation of the sunspot number (automated)
- Tracking of the long-term quality of the stations through the yearly determination of their scaling coefficient and daily dispersion. Those parameters form the main metadata associated with each individual station, retracing the whole history of its data production. This information is accessible by the station for its own evaluation and leads to direct personal communication with the station when a problem is detected.
- Coordinated research work with a community of international experts (Sunspot Number workshops, see sections R5 and R6 above) to assess all aspects of the sunspot number production and diagnose biases, errors, methodological flaws, etc. The international ISSI team of scientists works with WDC-SILSO team and provides comments and feedback as a user community (http://www.issibern.ch/teams/sunspotnoser/index.php/publications/). The scientific community at large provides feedback by using the derived sunspot series and referring to them in publications. As a specific example, in 2016, there was a topical issue of the journal Solar Physics dedicated to the sunspot number. All articles presented here use the series provided by the WDC-SILSO and provide feedback.

For the reasons mentioned above (software modernization in progress), no permanent technical documentation exists for the moment. However, the principles of the original processing of the sunspot number and of the recent end-to-end recalibration of the sunspot number V2.0 were presented in past articles:

https://doi.org/10.1016/j.asr.2006.12.045

https://doi.org/10.1007/s11207-016-1014-y

In addition to that, through the SIDC, hundreds of users have subscribed to the WDC-SILSO products (930 users for all WDC-SILSO products combined) and provide us feedback whenever they can through the silso.info@oma.be email address. Through the same email address, we answer all questions related to the series we provide for the public.

Reviewer 1:

Accept

Reviewer 2:

Accept

XII. Workflows

Compliance Level: 3

R12. Archiving takes place according to defined workflows from ingest to dissemination.

Different aspects of the archival workflow were presented in the previous sections R8, R9.

Overall the structure of the core workflow is rather simple and linear and can be summarized as follows:

- Raw input data are collected directly into a global database (input by the observers themselves)
- Those data are processed to produce daily sunspot number for one month at a time
- New monthly data are appended to the archive (provisional)
- With a three-month delay (when late observations have been entered by all stations), the provisional values are replaced by definitive values in the archive.
- The archive file (entire sunspot number series) is updated on our Web and FTP servers for dissemination.
- The archive file is preserved locally as part of the daily backup of the virtual machine on which is produced, next to copies on different local PCs.

This is the core workflow that defines the import of raw data, the archival and long-term preservation of our master sunspot series and its delivery to users.

The workflow becomes more complex when including the whole range of associated products derived from the main sunspot number production: daily estimated numbers, hemispheric numbers, graphics, and predictions. However, most of those products are not part of the central long-term archival and preservation process, but they complement the main data set to address specific needs of some user communities (space weather, solar dynamo modelling, and energy infrastructure managers). In that sense, the WDC-SILSO is equally a data repository and a service provider.

As mentioned several times, we are in the middle of the process of documenting the old procedures, improving them streamlining some of them and rewriting the software in a new modern form. The documentation will thus be built from all the elements that we collect and be based on the modifications we are now introducing. This is unfortunately a slow process because of our limited manpower and the need to also work in parallel on the improvement of the quality of the sunspot data series itself (new recalibrated versions. See sections R5 “Organizational Infrastructure” and R6 “Expert guidance”).

Reviewer 1:

Accept

Reviewer 2:

The documentation should be completed and made available by the time of the next review.

XIII. Data discovery and identification

Compliance Level: 3

R13. The repository enables users to discover the data and refer to them in a persistent way through proper citation.

Given the small set of data series maintained by the WDC-SILSO, the data discovery capacity is mainly based on the visibility of the SILSO Website. Once in the website, the user is guided to the data or associated products (graphics, predictions) by labelled sections. No search function is needed at this scale.

The Web page coding includes proper tags allowing efficient identification by the main search engines, like Google. Therefore, any search with the simple keyword "sunspot number" lists WDC-SILSO as the first hit for this subject, over more than 1,400,000 hits. With only "sunspot" as keyword, SIDC comes as 4th hit over 4,000,000. Therefore, we clearly achieve maximal discoverability for any user, scientist or general public.

As we don't openly distribute the raw data from our observing network, we did not develop a user interface for such searches. Those data are available on request to our base e-mail address silso.info@oma.be indicated on our webpages. However, as all our data have been ported to a MySQL database, those base data are thus fully searchable and can be made accessible if we decide to change our data policy regarding those raw observations.

For the same reasons, we don't openly cite all contributing stations, but the stations are listed in publications exploiting directly the raw data from the SILSO network (see, e.g., https://doi.org/10.1007/s11207-016-0875-4). In our plans, we would like to develop a "Network" section in the SILSO Website. This section would list all contributing stations (currently active) and past stations with some base metadata (name, geographical location, type of telescope), thus providing metadata about the input data sources. Note that this task requires some time and work, as past leaders of our WDC did not collect systematically those metadata. We thus have to reconstruct entirely past metadata and we need to make a survey of current stations (query form sent to all stations) to complete the present metadata. Here again, this is a pending action due to lack of manpower and the multiplicity of high-priority tasks (modernization of the data set itself). Next to the public part of this "network" section, there will be a login-protected section accessible only to our member stations, allowing them to check specific information like the history of the personal scaling coefficients, and possibly directly update their personal data (e.g. change of telescope).

For any use of our sunspot number series, we request proper citation, with a recommended formulation: http://www.sidc.be/silso/citations.

Definitely, the next improvement in data discoverability will be to attach permanent identifiers (DOIs). As explained in sections R3, R5, R7, R9, R10 and R13 above, this step is in preparation as part of the next upgrade of the data series, and the creation of an on-line data and software-sharing platform for experts involved in

this joint work (see data integrity and data quality sections). The mirroring of each release of a new version of our master data series on a repository (such as Zenodo) will automatically attach a DOI to each version, making the data series permanently discoverable independently of the use of the current SILSO Website. The WDC-SILSO team, in concertation with the scientists of the ISSI team, is examining the different options for obtaining said DOIs for our datasets.

Reviewer 1:

Accept

Reviewer 2:

The reviewers expect to see PIDs implemented by the next review. It is understood that because of the dataset at stake, a search function is not necessarily pertinent. However, for visibility purposes, adoption of machine harvestable schema would increase WDC-SILSO's impact.

XIV. Data reuse

Compliance Level: 4

R14. The repository enables reuse of the data over time, ensuring that appropriate metadata are available to support the understanding and use of the data.

All the sunspot data series distributed by the WDC-SILSO are fully documented through INFO keys attached to each data file. This provides a full description of the files and of each quantity listed in the files. A base description of the nature of the data is also provided. Now that we initiated the production of new versions (cf. other sections above), the changes between two versions is also fully described. Next to this summarized information, we provide links to peer-reviewed publications were the full description of the calculations or corrections can be consulted. See e.g. http://www.sidc.be/silso/newdataset, http://www.sidc.be/silso/versionarchive

In order to ensure best re-usability of the data sets even in a distant future, all base data are provided as simple uncompressed ASCII text files, lowering the potential compatibility issues with future software. For the convenience of some of our users, we started to produce files in CVS (comma separated values) format in 2014. This allows easy import into most spreadsheet or database applications.

Reviewer 1:

Accept

Reviewer 2:

Accept

TECHNOLOGY

XV. Technical infrastructure

Compliance Level: 4

R15. The repository functions on well-supported operating systems and other core infrastructural software and is using hardware and software technologies appropriate to the services it provides to its Designated Community.

WDC-SILSO benefits from a state-of-the-art IT infrastructure provided by the common resources of the hosting institution. This is definitely the main material support to the WDC, but it makes the WDC-SILSO operations entirely dependent on the externally managed infrastructure, of which it is only a very small "customer" among many other and bigger users (space projects, real-time operational services). The WDC-SILSO thus has very limited control on the overall strategies and policies of this technical infrastructure (data backup policy, network security, external access). So far, those strategies proved largely appropriate for the WDC purposes.

Finally, regarding the SILSO internal software, a thorough maintenance and upgrade effort has been undertaken, migrating the heritage software written in FORTRAN mostly to Linux Bash scripts and Python programs. Moreover, in the framework of the ongoing recalibration of the master sunspot number series, several aspects of the calculation method are reconsidered or expanded (e.g. error determination). Based on the findings, key methodological improvements will be incorporated in the main operational programs used to produce the new monthly sunspot numbers in the future. In this context, we are about to set up a GIT repository (GIThub) where the SILSO software will be stored, with version track, once the current global conversions and investigations will have reached maturity and the software will stabilize.

The technical infrastructure relevant to the WDC-SILSO is described in the Technical Infrastructure document available at http://www.sidc.be/silso/IMAGES/about/Technical_Infra_ROB_SILSO.pdf.

Reviewer 1:

Accept

Reviewer 2:

Accept

XVI. Security

Compliance Level: 3

R16. The technical infrastructure of the repository provides for protection of the facility and its data, products, services, and users.

For WDC SILSO, this security requirement is closely associated with the data preservation (backup) strategy, described in the data integrity and preservation sections above. In summary, this rests on:

- The multiplicity of copies of our core data set (small volume data) on several servers and personal PCs, some of them having their own backups (USB Hard-Disks)
- Systematic centralized backups of the servers running the virtual machines on which the WDC programs are run, as well as the Web, mail and FTP servers. Those snapshots allow to restore the servers in their past stable state in case of major problem.

Like for the technical infrastructure, the security versus malicious attacks is entirely relying on the ROB site-wide security strategy. Herewith, I include the answer from the ROB IT managers regarding the key questions about the network and server security.

The only WDC weakness on this point is the full outsourcing to the hosting infrastructure. In terms of network security, given the minimal staff of the WDC, we don't have the IT expertise on this highly technical aspect. However, the IT service is readily available and the technical infrastructure relevant for SILSO is described in http://www.sidc.be/silso/IMAGES/about/Technical_Infra_ROB_SILSO.pdf.

Reviewer 1:

Accept

Reviewer 2:

More evidence on documented procedures from ROB is needed for future certifications.

APPLICANT FEEDBACK

Comments/feedback

Some criteria are disproportionate for small data collections and small repositories like WDC-SILSO (e.g., IT technical and security standards). Producing evidence for some of the criteria in this new evaluation represented a significant additional workload.

This is even more the case, as in parallel, the WDCs must fulfil a formal scientific assessment (scientific validity of data). This further increases the workload, while the overarching scientific union has no funding to support such a process. Consequently, this extra work, inherent to the present existence of the WDCs, must be done without corresponding resources. This is a fundamental flaw in the current assessment scheme.

We thus hope that the evaluation will pragmatically take into account the limited resources and the narrower technical expertise inherent to such small repositories. Ensuring that the production and quality controls of the data are effectively done, with the often limited means, must remain the first consideration and priority.

ICSU
International Council for Science

Royal Observatory of Belgium

ICSU
WORLD DATA SYSTEM

Letter of Agreement between the WDC - "Sunspot Index and Long-term Solar Observations" (SILSO) and the International Council for Science (ICSU)

The purpose of this letter of agreement is to define the conditions under which the WDC - "Sunspot Index and Long-term Solar Observations" (hereafter WDC - SILSO) will contribute to the ICSU World Data System (hereafter ICSU WDS). This document is not legally binding.

1. The purpose of WDC - SILSO is primarily to maintain and distribute the International Sunspot Index based on visual sunspot observations made nowadays and over the past centuries. This includes the Zürich Sunspot Number initiated by R. Wolf in the mid-19th century and produced by the Zürich Observatory until 1980, and since 1981, the computation of the Sunspot Index based on a worldwide network (initially called Sunspot Index Data Center, SIDC). A central goal is to continue extending this unique secular record of solar activity, in support to solar cycle studies and investigations of long-term Sun-Earth relations. Additional data products have been introduced over the years to enhance and complement the base index, like the hemispheric sunspot index or mid-term forecasts of solar activity. Research activities are also carried out, e.g. to improve the long-term calibration of the current modern index and of the past series. For all those activities, WDC - SILSO can rely on the 75-year experience in ground-based solar observations available at the Royal Observatory of Belgium, which is running the Uccle solar station, one of the primary stations of the sunspot network since the Zürich era.

2. It is the intention of WDC - SILSO to contribute to the ICSU World Data System (WDS), and to collaborate with its governing body, the ICSU WDS Scientific Committee, in order to ensure the long-term stewardship and provision of quality-assessed data and/or data services to the international science community and other stakeholders.

3. By joining the ICSU WDS as a member, WDC - SILSO will work towards achieving the common goals and objectives of the ICSU WDS as stated in the constitution. These are to:

    a. Enable universal and equitable access to quality assured scientific data, data services, products and information
    b. Ensure long term data stewardship
    c. Foster compliance to agreed-upon data standards and conventions

ICSU
International Council for Science

Royal Observatory of Belgium

ICSU
WORLD DATA SYSTEM

d. Provide mechanisms to facilitate and improve access to data

4. WDC - SILSO commits to fulfil the ICSU WDS criteria for membership, including:
   a. Accepting the ICSU WDS Constitution 2012 (Annex A).
   b. Complying with the ICSU WDS Data Policy (Annex B) which include a commitment to full and open exchange of data, metadata and products deposited within the ICSU WDS.

5. If WDC - SILSO, for any reason is unable to continue its long-term commitment, then it should endeavour to find a mechanism to secure its data activities by transferring them to another ICSU WDS facility or other suitable host organisation.

6. The resources required for the data activities of WDC - SILSO are the responsibility of the Royal Observatory of Belgium (ROB). In order to provide continuity, the ROB will endeavour to provide these resources on a long-term basis.

7. This letter of agreement will enter into force upon signature by both parties. It is valid for an unlimited period from the date of signature.

8. This agreement is to be signed between ICSU and WDC - SILSO by the respective heads of organizations or their authorised delegates.

SIGNED
(On behalf of ICSU)

Date: 16/11/2012

Name: STEVEN WILSON

Position: ICSU, EXECUTIVE DIRECTOR

SIGNED
(On behalf of WDC - SILSO)

Date: 26/9/2012

Name: FREDERIC CLETTE

Position: WDC-DIRECTOR

AGREED BY
(On behalf of the hosting organisation)

Date: 25/09/12

Name: Ronald Van der Linden

Position: Director-general

Curriculum Vitae : Frédéric Clette

(September 2017)

Personal information

- Address: 30, rue des Échevins, 1050 Bruxelles, Belgium
- Date of Birth: 10 May 1961 (Schaerbeek, Brussels)
- Family status: married (Ann Herman, 31/3/1990), 4 children (ages 19- 25)

Education

- 1973-1979: secondary school, Athénée Adolphe Max (City of Brussels), orientation Latin-Sciences:
    - Since 1975: early interest in astronomy, amateur astronomer
    - Member of astronomical associations (Cercle Astronomique de Bruxelles, Société Royale Belge d'Astronomie)
- 1980-1983: Licence in Physics (Faculty of Sciences), Université Libre de Bruxelles (ULB):
    - Awarded grades:
        - 1ère Candidature (June 1980): Distinction
        - 2ème Candidature (June 1981): Distinction
        - 1ère Licence (June 1982): Grande Distinction
        - 2ème Licence (June 1983): Grande Distinction
    - Master thesis (June 1983): "La couronne solaire en lumière blanche polarisée : analyse des clichés de l'éclipse du 16 février 1980"
- 1984-1990: PhD thesis, Université Libre de Bruxelles (Promoter: André Koeckelenbergh, ULB/Royal Observatory of Belgium)
    - "Application de la photométrie solaire depuis le sol à l'observation des modes acoustiques globaux en intensité" (Supplementary thesis: "Modélisation de la phase T Tauri des étoiles d'une masse solaire").
    - Awarded grade: Grande Distinction (January 1990)

Scientific activities

1982-1983: Solar physics training (Royal Observatory of Belgium, ROB)

- **2-month training period** (experimental solar physics): optical calibration of the large solar spectrograph (Supervision: André Koeckelenbergh, Royal Observatory of Belgium)
- **Master thesis** (Supervision: André Koeckelenbergh, Pierre Cugnon, Royal Observatory of Belgium): reduction of the photographic images brought back by the Belgian expedition to the total solar eclipse of February 16, 1980 and taken in polarized light. Modeling of the Thompson-scattered K corona in order to derive the radial and latitudinal density

distribution of free electrons in the solar corona (1.1 to 2.5 radii). First refereed publication (Solar Physics journal)

1983-1989: PhD thesis (Royal Observatory of Belgium)

Defense: Université Libre de Bruxelles (Jan. 1990)

- **Subject**: Search for the signature of global solar acoustic oscillations (p-modes) in the full-disk solar intensity using high-resolution photometry from the ground.
- **Professional status**: IRSIA PhD grant (1983-1984), assistant under temporary contracts (Cadre Special Temporaire, 1985-1988)
- **Developments**:
    - Design, construction and operation of low-noise high-resolution photometers in two broad bands of visible light, in collaboration with the Royal Meteorological Institute (Atmospheric dynamics and Energetics section: Dr. D. Crommelynck): use of tension-frequency converters to achieve >20-bit digital resolution in intensity measurements
    - Organization of six observing campaigns in 1985-1986 from two mountain-top observatories: Pic—Du-Midi Observatory (France), Junfraujoch Observatory (Switzerland)
    - Development and implementation of Fourier-analysis software in collaboration with Dr. F. De Meyer (Royal Meteorological Institute)
- **Results**:
    - Detection of the strongest p-modes, with an amplitude of 10^{-5} relative to the total brightness of the solar disk. This first detection complemented the Doppler velocity measurements, which was the only technique used until then. It demonstrated the possibility of detecting Sun-like oscillations of distant stars by photometry of the start integrated intensity (achieved in the 1990s and 200's by the Corot (ESA) and Kepler (NASA) space missions). Refereed article in Astronomy & Astrophysics.
    - Application of the theory of dynamical systems (collaboration with Prof. C. Nicolis, Royal Meteorological Institute) to the turbulence in the Earth atmosphere, as revealed by the transparency noise. Demonstration that high-altitude atmospheric turbulence is non-stochastic but follows chaotic dynamics (attractor of finite dimension from 4 to 5), complementing earlier results from radar soundings.

1991-1999: Ground-based eclipse observations and analyses of the solar corona in polarized white-light

- **Subject**: Determination of the global electron density distribution in the solar corona based on photographic and CCD images of the linearly-polarized light from the K corona (Thompson scattering by free electrons) during total solar eclipses. This program was part of a series of Belgian expeditions (Expéditions Astronomiques et Géophysiques Belges, EAGB) initiated in

1972 by the Royal Observatory of Belgium and the Belgian Royal Military School and involving also a few experienced amateur astronomers.

- **Developments**:
    - Participation (1991) and lead-organization of Belgian expeditions (1994,1998,1999) to total solar eclipses, involving a group of 10 to 20 members (professional astronomers, meteorologists, amateur astronomers). All expeditions successfully brought back scientific images:
        - July 11, 1991 (Baja California, Mexico)
        - November 3, 1994 (Putre, Atacama, Chile)
        - February 26, 1998 (Curaçao Island, Dutch Antillas)
        - August 11, 1999 (Niederbronn, France; Ramnicu- Valcea, Romania)
    - Improvement to a photographic experiment: 3-position polarimeter upgraded to 6-positions, improving the measure of the plane of polarization
    - Design and implementation of a new CCD-based polarimetric imager, based on a CCD-video camera and motorized 12-position polarizing filter.
- **Results**:
    - Construction of a set of polarimetric images of multiple eclipses at various phases of the solar cycle (1972,1976,1980, 1983, 1991, 1994, 1998, 1999).
    - Derivation of absolute electrons densities in the lower corona 1.1 to 2.5 solar radii), a base reference for interpreting coronal emission lines recorded un the extreme-ultraviolet by space instruments (e.g. SUMER on the SOHO mission)
- **Scientific–educational project TECONet**: organization of an international coronal imaging campaign (Trans-European Coronal Observing Network) at the occasion of the 1999 "European" total solar eclipse. This campaign aimed at collecting a homogeneous set of photographic images of the corona. It was organized in the framework of the Joint Organization for Solar Observations (JOSO) a consortium of European ground-based solar institutes.
    - Recruiting and coordination of 30 amateur or professional stations distributed from France to India
    - Distribution and processing of calibrated film cartridges to all stations and a full manual describing the observing method.
    - Results: although it allowed to link a large community of amateurs on this unique occasion, this campaign did not deliver the expected scientific output, i.e. tracking the evolution of coronal structures over 2h 30min, much longer than the eclipse duration at a single site (2 min 30s). This was due to two adverse factors: bad weather of many regions, no solar transient during the time of the eclipse.

1984-1996: Contributions to the ground-based solar instruments of the ROB (optical, radio)

- **Uccle solar patrol station**:
    - Participation to the daily synoptic observations of the Uccle station over several decades

  - 1992: modernization of the recording software for daily measurements and tracking of sunspot groups
  - 1993-1994: acquisition of medium-resolution CCD images of the photosphere (whole-disk) in support to the ATLAS 1 and 2 missions of the Space Shuttle: mapping of sunspots and faculae to derive time variations of radiative deficits and excesses, in support to the radiometric measurements of the total solar irradiance by the space-borne absolute radiometer of the Royal Meteorological Institute (PI: D. Crommelynck)
- **Humain radio-interferometer**: Design and construction of a new video-based digital system for the high-rate acquisition (25 scans/s) of two-dimensional images of the radio corona for the receiver of the 48-antenna radioheliograph of the Humain radioastronomy station: after initial tests demonstrating that images could be obtained thanks to this new technology, this project could not be further developed due to the closing of this facility.

<u>1991 – 2002: Scientific Co-investigator for the Extreme-Ultraviolet Imaging Telescope (EIT) on the SOHO mission</u>

- **Main roles**:
  - Participation to the laboratory and in-flight photometric calibration of EIT: lead role for the determination of the flat-field corrections and their time evolution in flight
  - Participation to the instrument operations at the SOHO control center (NASA Goddard Space Flight Center, Greenbelt, USA)
  - Scientific study of the global statistics of nano-flares recorded in EIT coronal images.
- **Professional status**:
  - 1990-1996: Post-Doc contract (ESA PRODEX). First space-related position at the ROB.
  - 1/2/1996: Assistant in Solar Physics at the ROB (permanent position)
  - 1/3/1998: promotion to the grade of Work Leader (Chef de Trvaux)
- **Developments**:
  - **1993-1995: laboratory calibration of the flat-field of the EIT CCD camera** using synchrotron radiation at the Super-ACO facility (Institut d'Astrophysique Spatiale, Université Paris-Sud, Orsay, France):
    - Instrument control and data acquisition in a clean room environment
    - Implementation of mathematical techniques (Kuhn-Lin-Lorantz algorithm) for the extraction of corrections from non-uniform illumination sources.
  - **1996-1999: determination of the in-flight overall flat-field corrections** (CCD, optics, ageing)
    - Development of a new method allowing the determination of the in-flight flat-field corrections by exclusively using the EUV solar images (no proper

on-board calibration source): image integration, deconvolution, masking and Fourier techniques.

- First detection and determination of the non-uniform response degradation of the EIT CCD sensor caused by UV radiation and particles, including the changes induced by the accidental loss of the SOHO spacecraft during a few months in 1998 (loss of power and attitude).
- Calibration of the images from the CALROC ballistic flight (Naval research Laboratory, Washington DC, USA): characterization of the EIT aging using a short flight of its spare model.
- Inclusion of the initial corrections in the EIT main software library (IDL SolarSoft library).
- Lead author of a synthesis of the EIT overall calibration published as part of the ISSI Scientific Report SR-002 "The radiometric calibration of the SOHO mission" (2002)

- **1997-1998: Participation to the scientific operations of EIT and SOHO**:
  - 1995: participation to the pre-flight mission simulations at the NASA Goddard Space Flight center (GSFC)
  - 1996-1998: several missions as EIT Scientific Operator at the SOHO Operation Center (NASA-GSFC):
    - Daily planning of the EIT scientific program and instrument monitoring
    - Support to the general coordination of the 12 SOHO instruments, as main whole-disk monitoring instrument: report of the status of the Sun at the daily operation briefing.
    - Support to guest investigators for the definition and execution of dedicated multi-instrument campaigns.
  - Development and implementation of a "EIT high-cadence" SOHO Joint Observing Program:
    - Design and submission of a multi-instrument coordinated program dedicated to high-cadence imaging runs using the EIT at its highest imaging cadence (1 min) to record fast transients (nano-flares) in the quiet Sun.
    - This Joint Observing Program was repeated every few months over more than 6 years, allowing to compare this low-energy activity over different phases of the solar cycle.
- **Initiation of a new EIT-related spin-off project "EIT Data Exploitation"** aiming at extending the scientific benefit of the Belgian contribution to the EIT program:
  - Project submitted jointly with Pierre Cugnon, Head of the Solar Physics Department, to the Belgian Science Policy (Belspo):

        - Approved and funded, this project allowed to hire the first additional post-docs expanding the space-related scientific manpower of the Department (David Berghmans, Ronald van der Linden)
    - **1997-2004: Scientific study of small-scale micro and nano-flares recorded in EIT images** in two bandpasses, He II (transition region) and Fe XII (corona), and coronal rotation determination by tracking of coronal bright points:
        - Statistical analysis of thousands of events (automatic event detection, noise rejection), building on the expertise acquired through the participation to the instrument calibration and operations.
        - Determination of the occurrence rate, of scaling laws and of the energy spectrum (power law distribution), bringing new observational and quantitative evidence regarding the contribution of low-level quiet-Sun activity to the coronal heating and solar wind acceleration.
        - Determination of solar differential rotation by tracking coronal bright points in whole-disk EIT images (collaboration with Hvar Observatory and the Kiepenheuer-Insitute für Sonnenphysik, Freiburg).
        - Work developed jointly with D. Berghmans, leading to a series ofl publications.

2002-2004: Head of the Solar Physics Department of the ROB

In 2002, following the sudden illness and death of Pierre Cugnon, former Department Head, nomination as Head of Department.

- **Actions**:
    - Coordination of the Solar Physics team in a period of quick growth: staff growing from 15 to more than 40 members.
    - Overall management of the initial implementation of several new space projects brought by the success and recognition of the ROB contribution to the EIT space instrument and science (Invitation by former co-investigators in Europe and USA). This includes STEREO (NRL/NASA), AIA-SDO (NASA) and PROBAII (ESA).
    - Management of the development of the European Regional Warning Center (RWC) of the International Space Environment Service (ISES), taken over by the ROB-Brussels in 2000. Direct participation to the continuous service activities as Space-Weather forecaster.
    - Introduction of an internal accounting, for supporting the multiple projects under development (creation of a secretary position in the Department)
- In 2004, resignation from this full-time managing position, in order to again devote time to solar research, as this abrupt transition to a managing role in 2002 was justified by the need to ensure the stability of the Department across a sharp transition but came early it my scientific career.

2002-present: Modernization of the ground-based solar monitoring facilities of the ROB

- **Objectives**: Refurbishment, modernization and re-orientation of the existing but ageing solar optical and radio facilities of the Solar Physics Department at the Uccle and Humain stations, in order to restore their original function by defining new observational targets and introducing the latest technologies.
- **Development of new solar radio spectrographs at the Humain station**:
    - Following the closing of the 408MHz radioheliograph at the Humain station in 2005, introduction of a new project "HumSolar" proposing the refurbishment of a few existing parabolic antennas as decametric and centimetric radio spectrographs
    - 2008: Installation of a first decametric spectrograph CALLISTO in collaboration with the ETH Zürich (A.Benz, C. Monstein)
    - Start of a collaboration with the Dominion Radio Astronomical Observatory (Ottawa, Canada) for the development of a solar radiometer for the measurement of the standard flux at 10.7cm in Humain, complementing the unique instrument operated since 1949 in Canada.
    - Since 2008, those instruments were further developed by Dr. C. Marqué, recruited as part of the Solar-Terrestrial center of Excellence initiated by the Belgian Science policy in 2008.
    - Result: since 2008, continuous production of near real-time radio spectrographs and recording of solar radio busts (flares, coronal mass ejections) in support to the alert and forecast services of the RWC-Brussels
- **Development of new CCD-based solar patrol imagers at the Uccle Solar Equatorial Table (USET)**:
    - Definition and supervision of the technical upgrade of the USET telescope and dome control: full computerization of the controls, allowing remote operation, and currently being prepared for full automation.
    - Design, construction and operations of three new whole-disk solar imaging telescopes using low-noise digital CCD cameras:
        - 3 channels:
            - White-light (broad band, photosphere) since 2002
            - H-alpha (chromosphere) since 2002, equipped with a new Fabry-Perot monochromator
            - Calcium II K (chromosphere) since July 2012
        - Design of the optical systems and some mechanical components
        - Definition and supervision of the camera control software (development by IT graduate students and ROB programmers). Implementation of a USET Web portal for worldwide distribution of USET images in near real-time.
    - Result: imaging systems in routine operation, providing near-real time synoptic images in support of solar alert and forecasting services, and for the H-alpha

channel, to the Global High-resolution H-alpha Network (GHAN, worldwide network managed by the New Jersey Institute of Technology, USA)

- **Development of a new PC-based digitization system for the systematic measurement of the USET daily sunspot drawings**.
    - Definition and supervision of the development of the DigiSun application, allowing on-screen measurements of scanned sunspot drawings.
    - Software development of library modules (FORTRAN, C++): solar ephemeris, spherical and heliographic coordinate conversions.
    - Implementation of a global digitization project of the whole ROB sunspot drawing archive, initially as part of the EU-funded FP7 project SoTerIA. This project involved new research on existing long-term sunspot catalogues (Greenwich, NOAA-Boulder, Debrecen DPD), their standardization and merging, led by a newly recruited collaborator, Laure Lefèvre.
    - Results:
        - Construction of a state-of-the-art sunspot catalog and database of the complete USET drawing series (1939-now, > 20000 items). Since 2017, this catalog forms the base data for a new Val-U-Sun project (Belspo) aiming at the statistical exploitation of this large repository of active region properties.
        - Daily drawing digitization in support of the World-data Center SILSO for the Sunspot Number (daily Estimated International Sunspot Number) and since 2017, daily Ursigram-coded sunspot group data in support of the RWC-Brussels

2011-present: Direction and development of the World Data Center SILSO (Sunspot Index and Long-Term Solar Observations), member of the World Data System (ICSU, UNESCO)

- Since March 2011, main activity as Director of WDC-SILSO, hosted at the ROB since 1981.
- **Objectives**:
    - Modernization of the processing of current sunspot data from the SILSO worldwide network (85 stations) for the extension of the sunspot number series
    - Evaluation and correction of the long-term homogeneity of the 400-year sunspot number series, primary reference data for the reconstruction of the long-term solar activity (input to >100 research publications/year).
- **Developments (Operations)**:
    - Re-programmation and documentation of heritage processing programs written in FORTRAN and ported to modern languages (Unix Shell scripts, Python, PHP)
    - Modernization of the data archiving and distribution: complete database of raw sunspot data (37 years, 285 stations, 550,000 observations), graphics, new standard file formats.
    - Creation of a dedicated SILSO Web site (top Google ranking for the search keywords “sunspot” or “sunspot number”)

  - Development of new data products: near-real time Estimated Sunspot Number (EISN), Mc Nish & Lincoln cycle prediction software (collaboration with NOAA, Boulder, USA), repository for externally produced Group Sunspot Number series (auxiliary long-term index).
- **Developments (research)**:
  - Scientific investigation and determination of biases in the historical series 1700-1980: detection of a 15% drop in early data from R. Wolf over 1849-1865.
  - Investigation of the "Brussels" part of the sunspot number series 1981-present by exploiting the full database of 285 stations: full re-computation of the sunspot numbers, eliminating a 20% drift of the Locarno reference station, formerly used to calibrate the series on long timescales.
  - Organization, jointly with scientists from the National Solar Observatory (Boulder, USA) and Stanford University (San Francisco, USA), of a series of dedicated international Sunspot Number workshops, held from 2011 to 2014 (Sacramento Peak Observatory, USA; ROB, Brussels; Kitt Peak Observatory, USA, Specola Solare Observatory, Locarno, Switzerland)
  - In the framework of those workshops, coordination of joint investigations of both the sunspot number series and of the group sunspot numbers series: diagnosis of a major 40% drift in the group number series over 1885-1915, explaining a large part of the initial disagreement between those two long-term records of solar activity.
- **Results**:
  - 2014: in the framework of an ISSI workshop dedicated to the solar activity cycle (International Space Science Institute, Bern, November 2013), publication of a book chapter reviewing all diagnosed corrections to the original sunspot series.
  - July 2015: official release by the WDC-SILSO of the first revised version of the reference sunspot number series (numbered V2.0)
  - 2016: Guest Editor of a topical issue of Solar Physics, the main journal in the discipline, entirely dedicated to the recalibration of the sunspot number (author of 6 articles; with 30 contributed articles from various authors).
  - Since 2015, this seminal work produced a revival of the research in the reconstruction of past solar activity, leading to multiple new publications in the solar physics literature.
  - 2017: a new cycle of Sunspot Number workshops was proposed to the ISSI and accepted for 2018-2019

Other scientific activities:

- 2003-2013: Production of the "Sun" chapter of the Yearbook of the Royal Observatory of Belgium: high-accuracy ephemeris calculation of the Sun celestial coordinates, sunrise/sunsets and rotation.
- 2000-2008: Space Weather forecaster for the Regional Warning Center Brussels: activity monitoring, real-time alerts and daily forecasts of solar eruptive activity and of geomagnetic disturbances, distributed worldwide as part of one of the 13 warning centers of the ISES (monthly one-week shifts).
- 1983-present: operations and drawing/image acquisition at the Uccle solar station
- Reviewer for various articles devoted to solar activity, published in Solar Physics, Astronomy and Astrophysics and Space Weather (American Geophysical Union).

Education and public outreach

- 2004-present: **Maître de Conférence at the University of Liège**: 30-hour course "The Sun: structure, activity, and impact on the Earth Environment" as part of the Master in Astrophysics and Space Science of the Astrophysical Institute.
- 2010 and 2014: two public courses as part of the "Collège Belgique" of the Belgian Royal Academy of Sciences
- Numerous public lectures for various astronomical and non-astronomical associations in Belgium, and also France (Printemps des Sciences), Switzerland
- Various interviews for the media (newspaper, radio, television) about various astronomical or solar topics, at the occasion of special events (eclipses, exceptional solar events, etc.)
- Posters, public events and visits at the ROB (e.g. for the Open Doors week-ends)
- Numerous science popularization articles in "Ciel et Terre" and others astronomical publications for amateur astronomers.

Personalia

- Member of the International Astronomical Union (since 1997, Division E)
    - Member of Commission 12 (Solar radiation and structure)
    - Since 2014, co-Chair of the Inter-Division Working Group "Coordination of synoptic observations of the Sun"
- Royal Academy of Sciences of Belgium:
    - Member of the Sous-Comité d'Astronomie Spatiale (since 1996)
    - Member of the Committee for Space Research (since 2003)
    - Member of the Belgian Committee for Space Weather (since 2003)
    - Member of the Belgian URSI Committee (International Radio-Sciences Union)
- Member of COSPAR (Committee on Space Reasearch)
- Member of URSI (Unions des Radio-Sciences International), Commission J (Radioastronomy)

- 2012-2015: International Member of the MEDOC Steering Committee (MEDOC data center, Institut d'Astrophysique Spatiale, Orsay, France)
- Member of the Scientific Organizing Committee of the Coimbra Solar Physics Meeting (CSPM2015) in October 2015 and of the IAU Symposium 340 "Long – Term Datasets for the Understanding of Solar and Stellar Magnetic Cycle" to be held in February 2018.

Technical skills:

- **Observational astronomy**: control of large-size ground-based instruments (up to 1-meter aperture), space instrumentation (extreme-UV imagers, clean room environment), photometry, stellar/solar spectroscopy, spectral analysis of time series, ephemeris calculations.
- **Electronic imaging**: CCD technology (visible light and extreme-UV sensors and cameras), image processing (photometric corrections, spatial filtering, deconvolution),
- **Photography**: standardized darkroom processing (> 100 35mm solar eclipse films), characterization of emulsions (sensitometry, resolving power)
- **Computer**: MS Windows and Linux operating systems (shell scripting), programming in BASIC, FORTRAN77 and 90, C, IDL and Python (advanced), C++, PHP, MIDAS (base knowledge), MySQL database management, standard office suites (MS Office, LibreOffice), LaTex editing, GIMP
- **Electronics**: design and construction of digital and analogic electronics
- **Languages**:
    - French: mother tongue
    - English: fluent (written and spoken)
    - Dutch: passive knowledge (written, good oral understanding but not spoken)

Personal interests and hobbies:

Reading (astronomy magazines, etc.), photography, renewable energies, social initiatives (Amnesty International, cooperatives, etc.), gardening, do-it-yourself (woodwork, repairs), amateur astronomy, cycling (commuting, touring, travel), sandyachting (sailing, pilot license), traditional dances.

Laure Lefèvre

Royal Observatory of Belgium
Sunspot Index and Long-term Solar Observations (SILSO/SIDC)
Solar Terrestrial Center for Excellence (STCE)

Born Oct. 30th 1978 in Lyon 8ème
Nationality: French
Residence: Belgium

12 years of experience (August 2002)
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WORK

- Royal Observatory of Belgium: Nov. 2009- 2014 (postdoctoral researcher)

  European projects SOTERIA, COMESEP, SOLID and COST TOSCA action. **Long term Solar Cycle variations for its impact on Earth climate** (TOSCA). Standardization of available sunspot data and creation of homogeneous catalogs spanning centuries (SOTERIA, SOLID). Statistical analyses of solar indices from WDS-SILSO and work on long-term trends in the International Sunspot Number. Geomagnetic storms and their solar counterparts (COMESEP). Outreach and dissemination. Lead of the BRAIN.BE proposal SOLARIMPACT in the sleeping beauties axis. Work for the ESA-SSCC and the USET station. Scientific outreach in the TOSCA project.

- Observatoire de Paris – LESIA (Laboratoire d'Etudes Spatiales et d'Instrumentation en Astrophysique): May 2006 – August 2009 (postdoctoral researcher)

  CNES, "**Study of variable stars – spatial project COROT**". Study of the frequency spectrum of variable stars observed by the COROT satellite. Development of tools to analyze in-depth all the present frequencies. Determination, development, deployment and supervision of the treatment of data. Development of signal and image analysis tools and statistical analysis tools as well as adapted GUIs. Scientific outreach.

- Université de Montréal – Université de Strasbourg: Jan. 2002- Feb. 2006 (PhD work)

  Université de Montréal, ***Study of the different types of variability of massive stars*.** Photometry and Spectroscopy analysis of space and ground data. Development and deployment of the complete treatment for the MOST satellite data. Scientific exploitation of the analyzed data. Scientific outreach.

EXPERTISE

- Time series analysis, signal and image processing and statistical analysis, data mining.
- **Stellar Variability:** Discovery of the first stable pulsation period in a Wolf Rayet star. Analysis of spectroscopic data: existence and orbital period of WR137 companion. Variability of OB stars from the Hipparcos catalogue. Data Analysis Team and reduction pipeline for the COROT satellite.
- **Solar variability:** Identification, standardization, fusion and exploitation of catalogs on sunspot. Historical analysis/reconstruction of solar data. Analysis of the data, data mining, reconstruction of solar forcing indices and proxies for the determination of the influence of the Sun on our Climate. Exploitation of the WDS-SILSO database for statistical analysis and long-term calibration of the International Sunspot Series.
- Programming skills (IDL, Python, C/C++, Fortran, Java and SQL basics, html)

EDUCATION - DIPLOMAS

- *Jan. 2002 – Feb. 2006*: **PhD Thesis** Université de Montréal and Université de Strasbourg, 16 Feb. 2006 at Université de Montréal (Canada).
- *September 2001*:
  - **Engineer Diploma "Telecom Physique Strasbourg"**
  - **Master Astrophysics & Statistical Analysis**, Université de Strasbourg
- *Sept. 1998 – Sept. 2001*: **Telecom Physique Strasbourg**
- *Jun. 1996*: Baccalauréat Série Scientifique

PUBLICATIONS

Total papers: 35 (32 published +3 to be submitted by the end of 2014)
Refereed papers: 14

Laure Lefèvre is also a referee since 2010. She reviewed papers for Astronomy and Astrophysics (1), JAAVSO (1), Solar Physics (4) and the Astrophysical Journal (1).

INTERNATIONAL PROJECTS

- Management comity member for BELGIUM in **TOSCA (COST ES1005):** 2011- 2015
- International Collaboration Sunspot Workshops: 2011 - 2015
- Member of **European projects FP7: SOTERIA, COMESEP, SOLID**
  - SOlar TERrestrial Investigations and Archives: 2008-2011
  - **CO**ronal **M**ass **E**jections and **S**olar **E**nergetic **P**articles, (http://comesep.aeronomy.be/) : 2011 - 2014
  - **SOL**ar **I**rradiance **D**ata Exploitation (http://projects.pmodwrc.ch/solid/) : 2013 - 2016
- International project, COROT satellite: 2006 - 2009
- Canadian project MOST satellite: 2004 - 2006

Sabrina Bechet

PhD in Astroparticle physics
Experienced in numerical methods

PERSONAL INFORMATION

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Phone	+32 495 45 59 10
E-mail	`bechetsabrina@hotmail.com`
Nationality	Belgian

KEY COMPETENCIES

Scientific	Experience in astroparticle physics (PhD)
	Knowledge of particle and nuclear physics
	Experience in data analysis and advanced statistical methods
Numerical methods	Data analysis (ROOT, decision tree)
	Optimization methods (genetic algorithms, gradient)
	Monte-Carlo simulation of particles transport
	Particle-matter interactions modeling
Computing	Scientific and technical programming (C++, python, OpenMP,cmake)
	Linux OS, high performance computing
	Version control system (GIT)
Other	Efficient scientific communication (presentation, reporting)
	Experience in project management
	Experience of working in an international collaboration
Languages	French (C2), English (C1), Dutch (A2)

RELEVANT WORK EXPERIENCE

Applied physicist — Jan.2016 - Now

ELI-beamlines, Extreme Light Infrastructure,Prague, Czech Republic

Evaluation of the radiation field for the ELIMAIA beamline (protons up to 250 MeV) with Monte-Carlo simulation.

Applied physicist — Jan.2013 - Dec.2015

CENAERO, research center for numerical simulation, Belgium

Development of an optimization method based on genetic algorithms for treatment planning systems in hadron therapy (WIN-TPS project, collaboration with IBA).

Project manager for a study on fast treatment therapy for IBA.

Development of a simulation code for particle-matter interactions.

Supervisor of an internship on the use of Geant4 in particle therapy in collaboration with ULB.

Experimental physicist in astroparticle physics — Jan.2008 - Oct.2012

PhD in the IceCube collaboration

Development of an original reconstruction method for particle identification.

Part of the IceCube detector deployment at the South Pole.

Use of a complete Monte-Carlo simulation chain for a HEP experiment.

EDUCATIONAL BACKGROUND

PhD in astroparticle physics Jan.2008 - Oct.2012

Université Libre de Bruxelles ULB, Interuniversity Institute for High Energies

Title: "Recherche d'un flux diffus de neutrinos tauiques d'origine cosmique dans le détecteur IceCube" (Search for a diffuse flux of cosmic tau neutrinos in the IceCube detector).
Promoters: prof. K. Hanson and prof. D. Bertrand

Bachelor and master in physics Sept.2003-Aug.2007

Université Libre de Bruxelles ULB, Service de physique théorique

Master title: "Baryogenèse et matière noire" (baryogenesis and dark matter). **Promoter:** prof. M. Tytgat

RELEVANT PUBLICATIONS

Radiation protection of a proton beamline at ELI-Beamlines, JINST, S. Bechet et al 2016, JINST 11 C12019, December 2016

A Search for Ultrahigh Energy Tau Neutrinos with IceCube, IceCube Collaboration:R. Abbasi et al, Physical Review D86 (2012) 022005, 26 July 2012

An Improved Method for Measuring Muon Energy Using the Truncated Mean of dE/dx, IceCube Collaboration: R. Abbasi et al, Nuclear Instruments and Methods A703 (2013) 190-198, 1 March 2013