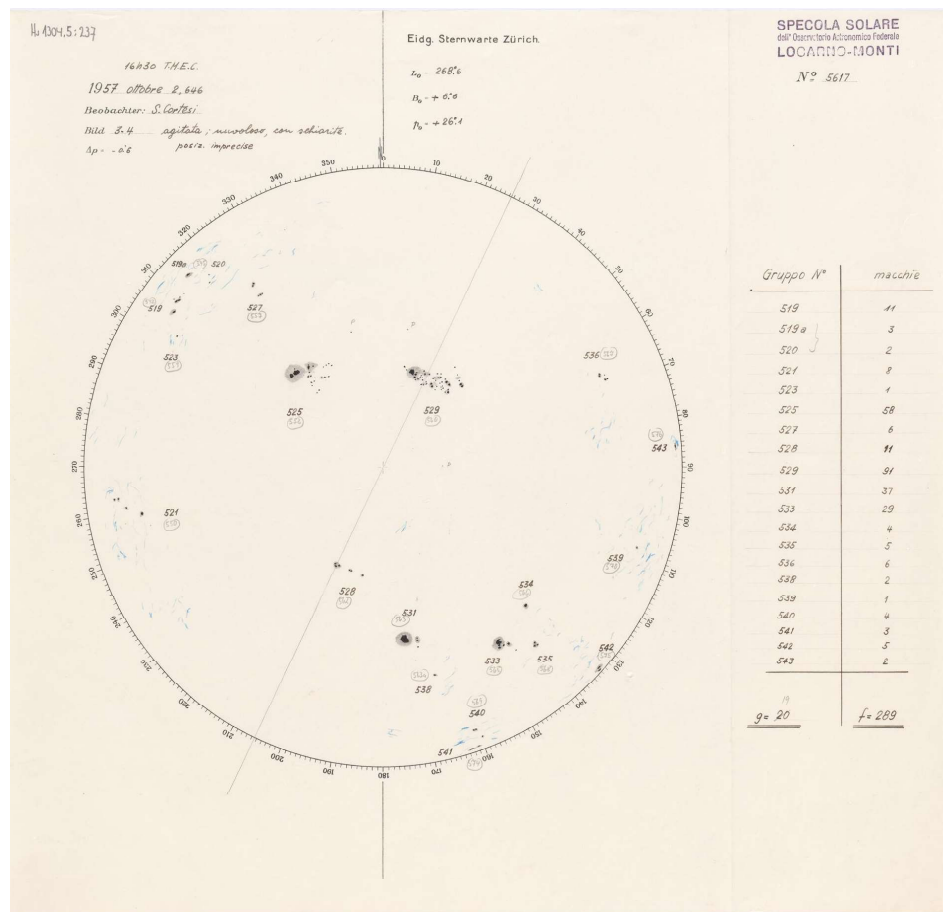


Final Scientific Report of the Archiving project of the Sunspot Drawings and data collected at the Specola Solare Ticinese in Locarno

with the support of the Federal Office of Meteorology
and Climatology MeteoSwiss, in the framework of GCOS Switzerland

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Sergio Cortesi's first drawing for the Specola Solare Ticinese. (Courtesy: ASST, HSA)

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1 Summary

The Sunspot Number (SSN) is a 400 year long observational data series that represents a valuable information not only for solar physics, but also for climate studies, in particular for its applications in the long term solar irradiance reconstruction. The observations at Specola Solare Ticinese (SST) in Locarno have played a major role in the determination of the international SSN data series in the past 66 years and since 1981 SST assumed the function as reference station for the world data centre (SILSO) at the Royal Observatory in Brussels.

The aim of this project has been to provide a safe long-term archiving and digitization of the sunspot data and drawings collected at the Specola Solare Ticinese (SST). The project has been carried out by the Associazione Specola Solare Ticinese (ASST) in collaboration with the ETH Library, where the sunspot drawings have been archived by the ETH Zurich University Archives (HSA) and digitized by the DigiCenter. Meanwhile, since 2016, the ETH Library has independently been pursuing a similar digitization project for the drawings and documents produced at the Federal Observatory in Zurich from 1884 onwards by Rudolf Wolf and his successors. All drawings are openly accessible on e-manuscripta, the web portal for digitized manuscript material from Swiss libraries and archives.

Another product of the project is a database of all sunspot groups observed at SST, with data including sunspot counts, coordinates, classification, observer, observing quality and time. This has been prepared by Specola Solare Ticinese and published on an open public repository and on the own website. These valuable data are thus available to the scientific community for further analysis. For long term preservation the database has also been saved at the ETH Data Archive.

2 Scientific report

2.1 Introduction

The Sunspot Number (SSN) (Fig. 1) is a more than 400 year long observational data series, that allows to directly determine the evolution of the solar activity and the solar cycle. Other proxies of solar activity are available nowadays but cover a much smaller measurement period. With the SSN it is also possible to study and calibrate the indirect reconstruction of the solar activity in the past millennia, based on the measurement of the cosmogenic radioactive nuclides C^{14} and Be^{10} in tree rings and in the polar ice caps (e.g. Muscheler et al. 2016), whose production rate depends on the solar activity. In fact, the heliospheric magnetic field is stronger at the maximum of solar activity and it better screens the charged galactic cosmic rays that trigger the production of the above mentioned radioactive nuclides.

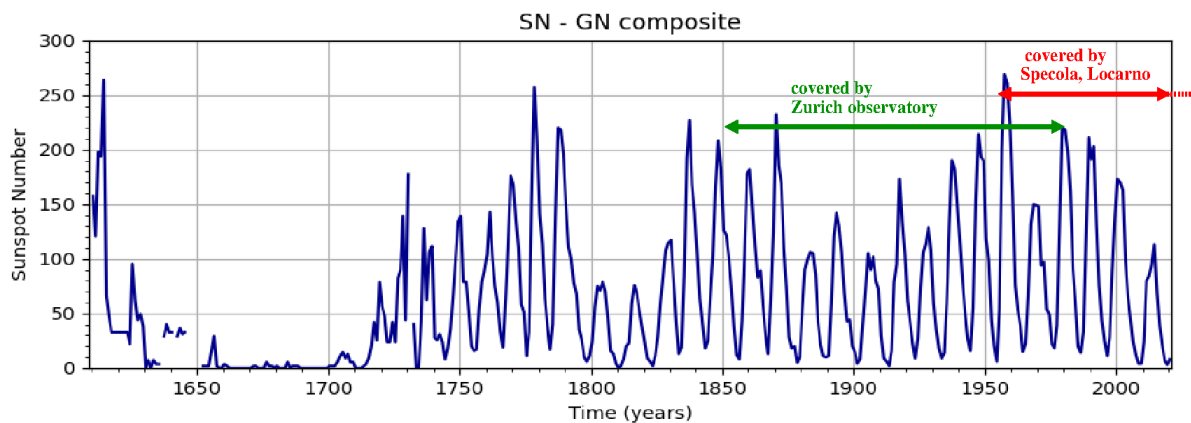


Figure 1 The Sunspot Number series show the typical 11-years solar activity cycle which is significantly correlated with small variations of the total solar irradiance. From 1645 to 1715 there was a grand minimum of activity when the solar cycle disappeared. The low activity during this period is called Maunder Minimum and occurred during the middle part of the Little Ice Age. (Credit: SIDC, Brussels)

The SSN is of interest to many fields including solar physics, Sun-Earth interaction (space weather), and climatology. On one side it provides constraints and validation for state-of-the-art models of the solar dynamo, developed nowadays. By reproducing the highly non-linear physics that generates the solar magnetic activity deep inside the Sun, those dynamo models can lead to predictive capabilities of the future evolution of solar activity, including the recurrence of episodes of Grand Minima, one of the key challenges in solar physics. Generally, more than 100 scientific publications per year refer to the Sunspot Number series. Thanks to its good correlation with the total solar irradiance (Fig. 2), the Sunspot Number (SSN) allows to study the variations of the solar radiation in the past 400 years (Kopp et al., 2016), well beyond the more recent measurements provided by satellites. For this reason, the SSN was recognized in the GCOS Implementation Plan published in 2016 as a valuable information for climate studies in particular for its applications in the long term solar irradiance reconstructions.

In 1848, the Swiss scientist Rudolph Wolf started systematic observations of Sunspots first in Bern and then at the Zurich federal observatory. He introduced as empirical index the Relative Sunspot Number R which is calculated as

$$R = k(10G + N)$$

where G is the number of observed sunspot groups, N the number of single sunspots and k an observer dependent normalization factor.

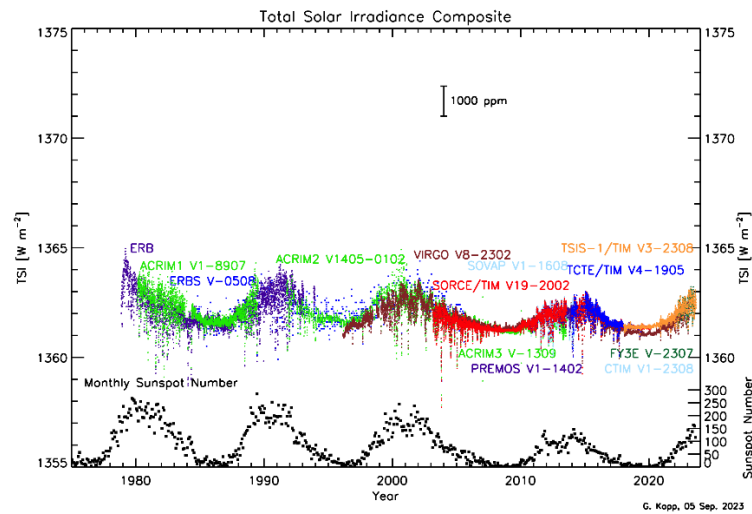


Figure 2 Sunspot Number and the Total Solar Irradiance measurements. (Credit: G. Kopp)

Wolf retrieved old data from different archives worldwide and could go back with the data series until the 17th century. Wolf's successors continued the observations in Zurich until 1981 (see Fig.3).



Figure 3 Historical telescopes at the Federal Observatory in Zurich. Left: The Fraunhofer 80 / 1100 mm refractor (64x) on the observation terrace of the Swiss Federal Observatory Zurich - in use since 1855 for daily sunspot observations, photo from 1949. - ETH-Bibliothek Zürich, Bildarchiv: PI_49-B-0193. Right: Solar telescope, ETH Zürich, Eidgenössische Sternwarte, Hauptkuppel, 1930 - ETH-Bibliothek Zürich, Bildarchiv: Ans_05063-003

Specola Solare Ticinese (Fig. 4) started its operation in 1957 as an external observing station of the Zurich observatory (Cortesi et al., 2016). Since 1981 Specola operates independently and since then, thanks to the long experience acquired when it was an external observing station of the Zurich observatory, it is recognized as pilot station by the SILSO World Data Center at SIDC in Brussels (Clette et al. 2016). This could guarantee the long term homogenization of the Sunspot Number data series. Data collected daily at the SST are published in digital format on its webpage and sent to SILSO.



Figure 4 The observatory at Specola Solare Ticinese in Locarno. The solar telescope can be seen in the window of the dome.

In the past decade the international scientific community envisaged a large effort in a better homogenization and SILSO published a revised version of the Sunspot Number series (Clette & Lefèvre, 2016). The effort is still continuing. A dedicated scientific team has been created at the International Space Science Institute (ISSI) in Bern and worked on the topic in the past years (Clette et al. 2023). As a result, a new improved revised version of the SSN is foreseen to be announced at the next general assembly of the International Astronomical Union (IAU) that will take place in 2024 in Cape Town.

Presently the SSN determination is still based on visual observations and counting. Until now this could better achieve the requirements related with the homogenization of the past data series. It has also been possible to apply crosschecks thanks to the availability of observations from several observatories worldwide, some of them, like the Specola, operating for several decades with the same instrument and the same observers (S.Cortesi observed at SST for 64 years!). Recently an interactive software developed at SILSO and called Digisun has been routinely implemented for the analysis of the Sunspot drawings at SST, allowing to easily retrieve information, e.g. about the sunspot area in unit of millionths of hemisphere, the magnetic dipole, the sunspot group coordinates and their classification.

The main goal of this project has been the long-term preservation and dissemination of the observations acquired at Specola (Ramelli et al., 2019). Therefore, all sunspot drawings recorded at the Specola from the beginning of its operation have been safely archived and catalogued at the ETH University Archives. All those drawings have been digitized in good quality and published on e-manuscripta, the web portal for digitised manuscript material from Swiss libraries and archives. A sunspot group digital database covering all data collected at SST since the beginning of its existence has been prepared, published on the public data repository Zenodo and safely stored for a long-term preservation at the Data Archive at ETH Zurich.

All the original drawings collected until 2019 are now safely archived at the ETH Zurich University Archives. Their cataloguing, digitization and publication on the e-manuscripta portal has been completed in 2023.

2.2 Methods and activities

Safe archiving of the sunspot drawings

The sunspot drawings of the Specola Solare Ticinese (SST) observatory in Locarno-Monti was handed over for safe archiving to a professional archive, the ETH Zurich University Archives. This concerns a total of 11'693 drawings from the years 1981 to and including 2019, namely from the beginning of the period when SST became independent and was managed by a dedicated association (Associazione Specola Solare Ticinese). For this purpose, a contract for archiving (private archives section of the HSA) was prepared and concluded. This contract mentions possible additions for the recent and future sunspot observations carried out at SST.

This storage of sunspot observations directly follows the series already made by the same station and instrumentation in Locarno-Monti, but still under the aegis of the Federal Observatory of the ETH Zurich under Professor Max Waldmeier. These records from the years from 1957 to 1980 were also processed by the ETH University Archives and were made available for research in an identical way.

All sunspot drawings of the Specola Solare were processed according to the international standard for archival cataloguing and the corresponding metadata were published in the online catalogue of the University Archives. The scan of every single sunspot drawing is accessible on e-manuscripta, the Swiss web platform for digitized archival documents. They are provided with a digital object identifier (doi) via which the metadata in the catalogue of the University Archives is linked to the scan in e-manuscripta.

Furthermore, the drawings can be found on Archives Portal Europe, the platform of archives from more than 30 countries, as well as on the Swiss archival platform "Archives online". Since the beginning of the gradual publication, they are completely searchable on the national library platform "Swisscovery", with a link to the platform e-manuscripta (www.e-manuscripta.ch).

The original sunspot drawings were repackaged according to archival standards and are now securely stored in the ETH University Archives.

The drawings of the Specola Solare (Hs 1304.6) follow a series of records that began as a daily sequence of projection image drawings at the Swiss Federal Observatory in Zurich in 1884. A separate sub-collection (Hs 1304.2) exists for this series from Zurich. It comprises 41'156 documents, which were processed in parallel to the project. Among them are all those drawings that were sent to the observatory in Zurich from all over the world until 1980. This does not include the significant stock of drawings of the Specola Solare from 1957 up to and including 1980, for which a separate sub-stock (Hs 1304.5) was formed. The projection drawings from 1957 to the end of 1980 comprise a total of 7'386 originals.

Digitisation and publication of the sunspot drawings

All drawings were scanned at 300 dpi by the DigiCenter (Fig. 5) of the ETH Library. An accompanying color checker verified the color profile of the drawings. After quality control by the University Archives, the scans in tif format delivered from the DigiCenter to the ETH University Archives were also handed over to Specola Solare for evaluation during the course of the project.



Figure 5 . Digitization Center of the ETH Library, ETH-Bibliothek Zürich, Bildarchiv / Fotograf: Blaser, Frank / KOM_000273

The scans were prepared for presentation using the Visual Library Manager software and were gradually published online on the e-manuscripta platform. This process was completed before mid-May 2023. The last drawing of 31.12.2019 was made available online on 8.5.2023. It is tagged with a digital object identifier (DOI) like all other drawings to ensure citation security even if the Uniform Resource Locator (URL) would change. In e-manuscripta, various interfaces are available for the extraction and further use of data and they are documented in a manual (<https://www.e-manuscripta.ch/wiki/apiinfo>).

Sunspot Group Database

Another goal of the project was the production and the publication of a sunspot group database. Originally it was foreseen to collect in the database the following information for each observed sunspot group:

- incremental number
- heliographic latitude
- type according to Zurich classification
- sunspot counting

and for each observation:

- date and time
- image quality
- observer
- drawing identifier

All this information is noted by hand on the current drawings and can just be manually copied in the database. However, when the sunspot drawings produced before year 1980, that were already stored at the HSA, was delivered in digital format to Specola, it was discovered that the latitude and the classification was not directly written on those old drawings. The classification was then judged a posteriori by the operator in charge of preparing the database. It was possible also to find a solution to quickly determine the solar heliographic coordinates, including the declination of the sunspot groups, by using the software called Digisun, which has been made available by the SILSO data center. This allows to analyse the drawings interactively in a semiautomatic way. The operator still needs to select with the mouse the solar limb, the solar center and each sunspot group center. Then all calculations

are automatic and the data go directly into the database. Digisun provides other functions like the determination of the sunspot area and of the magnetic dipole, which are applied routinely on the new drawings, but could not be included in the processing of the old drawings because too time consuming for what it was planned in the present project proposal.

With these tools, it was then possible to complete the database with all planned entries from 1957 to now and to publish it on the public repository Zenodo maintained by CERN (Geneva), that follows the FAIR (findability, accessibility, interoperability, reusability) principles. Furthermore a WEB interface was developed to browse the database and the drawings on <https://sunspots.irsol.usi.ch> with direct links to the corresponding scan on the E-Manuscripta platform.

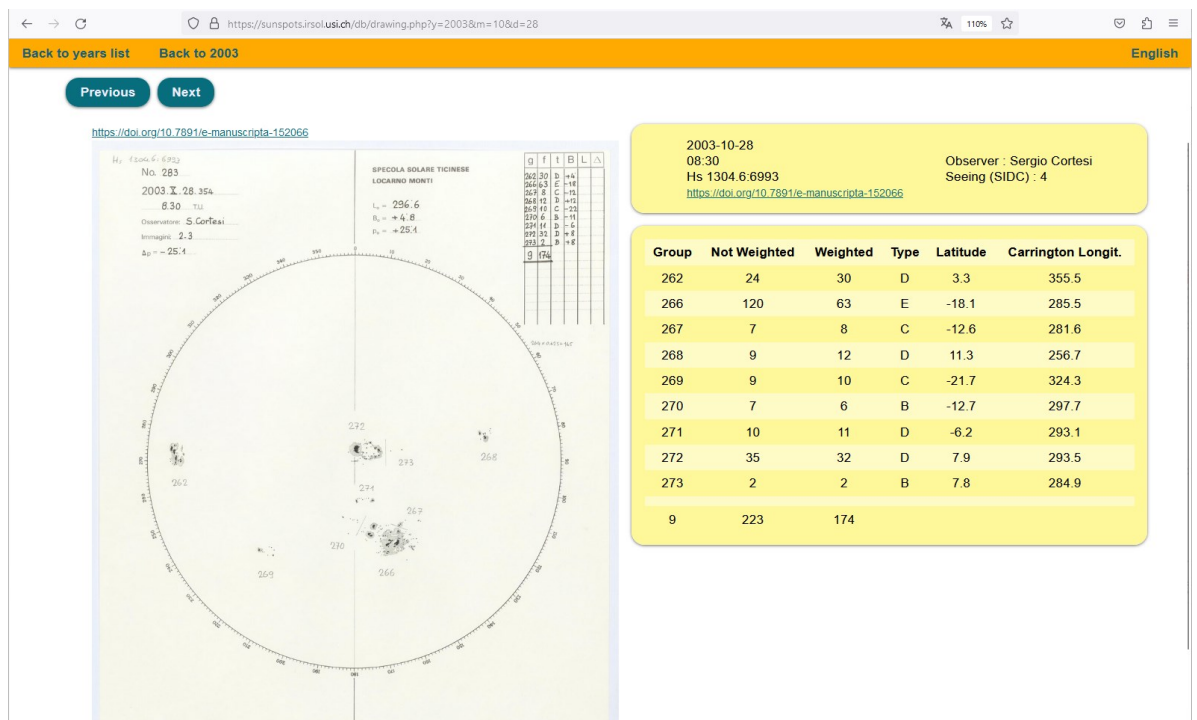


Figure 6 The web interface <https://sunspots.irsol.usi.ch> to browse the database and the scanned sunspot drawings

2.3 Results

This project allowed to safely archive and store all observational material acquired at Specola Solare Ticinese to study the solar activity cycle, to digitize and to publish it on open platforms and repositories. The published material represents a benchmark that is made available to the scientific community, from solar physicists to climatologists. The authors got already some particular requests by scientists for the direct access to the data. Furthermore the material produced in this project has already been used or cited in some scientific articles (e.g. Clette et al. 2023, Pevtsov 2023, Tlatova et al. 2022).

The collaboration with scientists and archivists in this project allowed to find new synergies that lead to new data products, improvements of the methods and results. An example is the additional information extracted from the drawings thanks to the above mentioned Digisun software developed by SILSO and since few years used routinely at Specola. Another result achieved thanks to the work done on the archived documents of Specola, led to the publication of new interesting findings about the past Sunspot data and the homogenization of the SSN (Clette et al. 2021).

2.4 Conclusions and limitations

The work planned in the project could be completed. All sunspot observations acquired at Specola Solare Ticinese since the beginning of operation in 1957 and up to 2019 could be safely archived, processed, catalogued, scanned at high quality and published online. One additional year has already been added with respect to the original plans in the proposal to cover the drawings up to the year 2018.

A database of all sunspot group observed at Specola has been produced and published. The database is filled and updated daily with the new observations performed at Specola.

Some initial difficulties with the extraction of all data needed for the insertion in the database, in particular the latitude of the sunspot groups, have been overcome thanks to the Digisun software provided by the SILSO data center. The same software allows the extraction of additional information like the total sunspot area, the dipole and the Carrington longitude that is now routinely acquired and inserted in the database with the new observations. The extraction of this additional information (not foreseen in the original proposal) from the older observations could not be fully done yet, because of the limited human and financial resources. In fact to obtain this information correctly, some relatively time consuming manual interactive operation is needed. Specola is trying to acquire additional fundings to add these additional data in the database also for all past observations.

2.5 Outreach work, publication of data and results

Websites:

The project was announced on the websites of all partners:

- www.specola.ch
- www.library.ethz.ch
(<https://library.ethz.ch/en/about-us/our-profile/projects/digitization-of-sunspot-drawings%20.html>)
- www.irsol.ch
- www.meteosuisse.admin.ch

News on Websites:

- "The Locarno station just completed a 5 year digitization project", 2023, News about the project conclusion on the SILSO world data center website:
<https://www.sidc.be/SILSO/article/locarno-completes-5-year-digitization-project>
- "GCOS-funded five-year project about sunspot data concluded", 2023
<https://www.specola.ch/en/gcos-funded-five-year-project-about-sunspot-data-concluded/>
<https://www.irsol.usi.ch/blog/gcos-funded-five-year-project-about-sunspot-data-concluded/>
- "Concluso il 4. anno del progetto finanziato dal GCOS", 2022
<https://www.specola.ch/concluso-il-4-anno-del-progetto-finanziato-dal-gcos/>
- "Archiving project of Specola Solare Ticinese sunspot drawings in collaboration with ETH-Zurich University Archives and GCOS", 2018, <https://www.irsol.usi.ch/?p=1240>
- The ETH Library's storytelling platform explora.ethz.ch has published an article entitled "Fackeln, Flecken, Flares - Sonnenforschung an der ETH Zürich" (Faculae, Spots, Flares - Solar Research at ETH Zurich), which, among other things, deals with the topic of sunspot observation. The digitisation and exploitation project as well as the current activities of the Specola Solare Ticinese can be seen in more detail in an interview with Renzo Ramelli.
- On November 14, 2018, the research community was informed through the news release Valuable astronomical notebooks on "Zurich sunspot relative number" online about the progress of the online publication of sunspot data.

Publications:

- Clette, F., Lefèvre, L., Bechet, S., Ramelli, R., and Cagnotti, M., "Reconstruction of the Sunspot Number Source Database and the 1947 Zurich Discontinuity", *Solar Physics*, vol. 296, no. 9, 2021. doi:10.1007/s11207-021-01882-6.
- Gasser, M., Graf, N., Huber, C., "Sunspot observations and glacier images: Archival research partnerships focusing on modern climate research", *Comma*, vol. 2021(2), p. 283-296. doi: [10.3828/coma.2021.27](https://doi.org/10.3828/coma.2021.27).
- Aktivitäten 2020 kompakt S. 45, in: *Kaleidoskop 2020*, hg.v. ETH-Bibliothek Zürich, Mai 2021
- Ramelli, R., Cagnotti, M., Cortesi, S., Bianda, M., and Manna, A.: 2018, Sunspot data collection of Specola Solare Ticinese in Locarno, proceedings of the IAU-Symposium, Vol. 340, 129

Presence in the media:

- The project has been mentioned in some interviews given by Marco Cagnotti at RSI (Radiotelevisione Svizzera).
- "Archive der Sonnenbeobachtung", 2021, article written by Duncan Pappert describing the project, ProClim Flash - issue 76.
- «Il sole che manda in blackout tutto il pianeta? "È possibile"», Ticinonline, 26.09.23 <https://www.tio.ch/ticino/attualita/1699813/tempesta-geomagnetica-blackout-potrebbe-sole>
- «Con gli occhi verso il sole in attesa del grande buio», 20 minuti, 26.09.23
«Il blackout che verrà dal Sole», 20 minuti, 26.09.23
<https://epaper.20minuti.ch/date/650/2023-09-26>
- Cagnotti, M., "65 anni di osservazioni del Sole finalmente disponibili online", *Meridiana* (bulletin of ASST and of Società Astronomica Ticinese, SAT) to appear in the next issue

Communication projects:

- A communication project "The Sun: our star" (PI: R.Ramelli), supported by the SNSF Agorà program, started on 1. September 2022. This project includes an interactive exposition inaugurated on September 16th 2023 at the outreach center of Università della Svizzera italiana: L'Ideatorio. The project envisages also continuous training courses for teachers and open-door days at Specola and IRSOL. The digitized material produced thanks to this project supported by GCOS is used in this communication project.

Conferences and presentations:

- Ramelli R., "Sunspot data collection and archiving at Specola Solare Ticinese", IAU-Symposium 340: Long-term datasets for the understanding of solar and stellar magnetic cycles, Jaipur, India, 20 February 2018.
- Ramelli R., "The digitization of the Swiss historical sunspot observations and its relevance for the Sunspot Number data series.", 3rd Swiss SCOSTEP workshop, PMOD Davos, 6 March 2019
- Ramelli R., Cagnotti, M., Boesch, E., Huber, C., "Archiving and Digitization of the Sunspot observations", Swiss National GAW/GCOS Symposium, 13 September 2021
- Ramelli R., "Observations and instrumentation at IRSOL: present and future", Swiss SCOSTEP workshop, Windisch, 16th May 2023, (one slide was dedicated to advertise the results of the is project).

Publications of data and results:

- All digitized sunspot drawings have been published with open access on the e-manuscripta portal <https://www.e-manuscripta.ch/>. Metadata with links to the scans on e-manuscripta can be found on the platforms Swisscovery (<https://swisscovery.slsp.ch/discovery/>), Archives Online (<https://www.archives-online.org/Search>), and Archives Portal Europe (<https://www.archivesportaleurope.net/>).
- The sunspot group database is published with open access according to the FAIR principle on Ramelli, Renzo, & Cagnotti, Marco. (2023). Sunspot Group Database of the Specola Solare Ticinese (Version 2023A) [Data set]. Zenodo. <https://doi.org/10.5281/zenodo.8117331>
- The sunspot group database can also be accessed through the interactive Web interface managed by Specola and IRSOL at <https://sunspots.irsol.usi.ch/>
All Specola sunspot drawings published on e-manuscripta have been linked to this Web interface.

The project progress has been mentioned and described in all institute annual reports of HSA, SST and IRSOL.

Student works:

The matura work of two students from Liceo di Bellinzona and followed by R. Ramelli (in 2019 and in 2021) were related with sunspot data made available through this project.

2.6 Outlook

The sunspot drawings are still performed and processed daily at Specola. The objective is to continue the data series as much as possible, to provide these valuable data to scientists and that Specola continues to play the prominent role of pilot station for the determination of the Sunspot Number also in the future. The acquisition of sufficient financial resources for this purpose in the future will be a requirement.

The Digisun software provided by the scientists from SILSO at the Belgium Royal Observatory in Brussels in the framework of this project is regularly used to process the sunspot drawings and to fill the Sunspot Group Database with the new observations. It is planned that updated versions of the database that includes the new observations will be published on a yearly basis on the Zenodo public repository and stored at ETH Data Archive also in the future. The donation agreement allows for an uncomplicated continuation of the archiving of current and future drawings at the ETH Zurich University Archives at some point in the future. However, this has not yet been discussed.

As already mentioned, the Digisun software allows to extract more data than originally foreseen in the present proposal, like the total sunspot area, the magnetic dipole orientation and the sunspot group latitude. The extraction of some of this information from the past drawings is still in progress and is part of a follow-up project of Specola financed by Canton Ticino through the Swisslos fund. Another topic of interest that will be addressed in the follow-up project, is related with different counting methods. In fact, at some point, the successors of Rudolph Wolf at the Federal Observatory in Zurich, introduced a weighted counting method where the sunspots are weighted according to their size. For instance, a large sunspot with penumbra is counted 3 or more, while a single small spot is counted 1 (Waldmeier, 1948; Cortesi et al. 2016). When this method was exactly introduced is still under debate. In any case, at the era when Prof. Waldmeier was director of the Federal Observatory between 1945 and 1979, this was routinely used. In the new SSN version that became official in 2015 (Clette & Lefèvre, 2016), the reference counting method is based on an unweighted counting, where each sunspot is counted as one regardless of its size. The effect of the different counting methods has been studied by Svalgaard et al. (2017) together with Specola collaborators. Both counts with the two methods are already partly present in the Sunspot group database of Specola, namely since year 1981. The goal would be to complete the unweighted sunspot count a posteriori on the drawings, back to the opening of the Specola in 1957.

A research team of experts has been very active in the past years to further improve the homogenization of the Sunspot Number. After the SSN revision (Clette & Lefèvre 2016) has been introduced and approved by the assembly of the International Astronomical Union (IAU) in 2015, further studies have been carried out. This resulted in a further revision that will be presented at the IAU assembly in 2024 (Clette et al., 2023). This work and activity show that the data produced by Specola and ETH in this project are still of very high interest for the present research and will help the scientists to better describe the solar cycles and to pursue the objective of a good homogenization of the SSN data series.

2.7 Acknowledgements

This work has been possible thanks to the financial support of the Federal Office of Meteorology and Climatology MeteoSwiss, in the framework of GCOS Switzerland. The authors would like to thank the collaborators of ETH Zurich University Archives, the DigiCenter and the ETH Data Archive for the collaboration in this project. The authors acknowledge the support of the staff of the SILSO data center by providing the Digisun software and advice, in particular to Frédéric Clette and Sabrina Bechet. The database WEB interfaces for the project were developed with the collaboration of Christian Skorski and Bruno Barbieri. Specola Solare Ticinese is supported by Canton Ticino through the Swisslos Fund. This work would not have been possible without all patient observations made by the Sunspot observers at Specola. In particular the authors would like to dedicate this work to the main past observer Sergio Cortesi (1932-2021).

2.8 References

- Clette, F., Lefèvre, L., 2016, "The New Sunspot Number: Assembling All Corrections", *Solar Physics* 291, 2629, doi:10.1007/s11207-016-1014-y
- Clette, F., Lefèvre, L., Cagnotti, M., Cortesi, S., Bulling, A., 2016, "The Revised Brussels-Locarno Sunspot Number (1981 - 2015)", *Solar Physics*, 291, 2733, doi:10.1007/s11207-016-0875-4
- Clette, F., Lefèvre, L., Bechet, S., Ramelli, R., Cagnotti, M., 2021, "Reconstruction of the Sunspot Number Source Database and the 1947 Zurich Discontinuity", *Solar Physics* 296, 137, doi:10.1007/s11207-021-01882-6
- Clette, F. et al., 2023, "Recalibration of the Sunspot-Number": Status Report, *Solar Physics* 298, 44. doi:10.1007/s11207-023-02136-3
- Cortesi, S., Cagnotti, M., Bianda, M., Ramelli, R., Manna, A., 2016, "Sunspot Observations and Counting at Specola Solare Ticinese in Locarno Since 1957", *Solar Physics* 291, 3075, doi:10.1007/s11207-016-0872-7
- Kopp, G., Krivova, N., Wu, C.J., Lean, J., 2016, "The Impact of the Revised Sunspot Record on Solar Irradiance Reconstructions", *Solar Physics*, 291, 2951, doi:10.1007/s11207-016-0853-x
- Muscheler, R., Adolphi, F., Herbst, K., Nilsson, A., 2016, "The Revised Sunspot Record in Comparison to Cosmogenic Radionuclide-Based Solar Activity Reconstructions", *Solar Physics* 291, 3025, doi:10.1007/s11207-016-0969-z
- Pevtsov, A., 2023, "Long-term Solar Variability: ISWAT S1 Cluster Review for COSPAR Space Weather Roadmap" (2023) to appear in *Advances in Space Research*
- Ramelli, R., Cagnotti, M., Cortesi, S., Bianda, M., and Manna, A.: 2018, Sunspot data collection of Specola Solare Ticinese in Locarno, proceedings of the IAU-Symposium, Vol. 340, 129
- Svalgaard, L., Cagnotti, M., Cortesi, S., 2017, "The Effect of Sunspot Weighting", *Solar Physics*, 292, doi:10.1007/s11207-016-1024-9
- Tlatova, K.A., Vasiliev, V.V. & Tlatov, A.G., 2022, "Analysis of the Area in Groups of Sunspots of Different Classes", *Geomagn. Aeron.* **62**, 839–844
- Waldmeier, M.: 1948, "100 Jahre Sonnenfleckenstatistik", *Astron. Mitteil. Eidgn. Sternw. Zürich*, 152.