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Article 1:

New ^{14}C-Based Reconstructions of 11-Year Solar Cycles: Longer Than a Millennium Now

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It was known for a long time that dark spots, occasionally observable by naked eyes, can appear on the Sun, but their nature and even very belonging to the Sun was unclear. Scientifically, the sunspots were discovered and confirmed as such in the earlier 17th century (see a review by Arlt & Vaquero, 2020). The main pattern of sunspots occurrence is that they tend to appear in the course of the solar cycle which takes about 11 years on average (Hathaway, 2015). The existence of the 11-year cycle was first proposed by the Danish astronomer Christian Horrebow in the 18th century and finally discovered by the German astronomer Samuel Heinrich Schwabe in the middle 19th century. It is now called the *Schwabe* cycle with a duration of about 11 years on average ranging from 8 to 16 years for individual cycles. Solar cycles are subsequently numbered by Rudolf Wolf starting from 1749. The period covered by telescopic sunspot observations since 1610, includes also the Maunder minimum, viz. the period of very low solar activity when the Sun displayed virtually no spots (Eddy, 1976).

For the period before 1610, solar variability can only be studied using indirect cosmogenic-isotope proxy datasets (Beer et al., 2012; Usoskin, 2017), which are usually of low temporal resolution and cannot resolve individual solar cycles. A breakthrough has been made recently thanks to the high-precision annual meas-

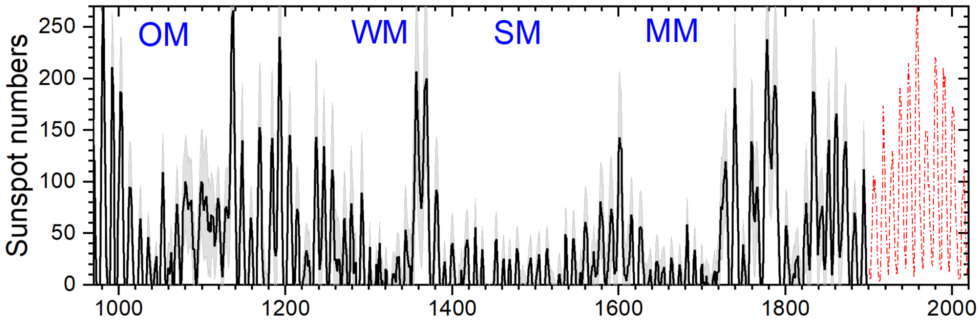

Figure 1. Sunspot numbers reconstructed from annual Δ^{14}C data (black line) with ±1σ uncertainties (grey shading) for the period 971—1900 (digital data are available in Usoskin et al., 2021). The annual ISN (v.2) dataset (https://wwwbis.sidc.be/silso/datafiles) is shown with the dotted red line. Approximate timing of the grand minima (Oort – OM, Wolf – WM, Spörer – SM, and Maunder – MM) are indicated with the blue letters.

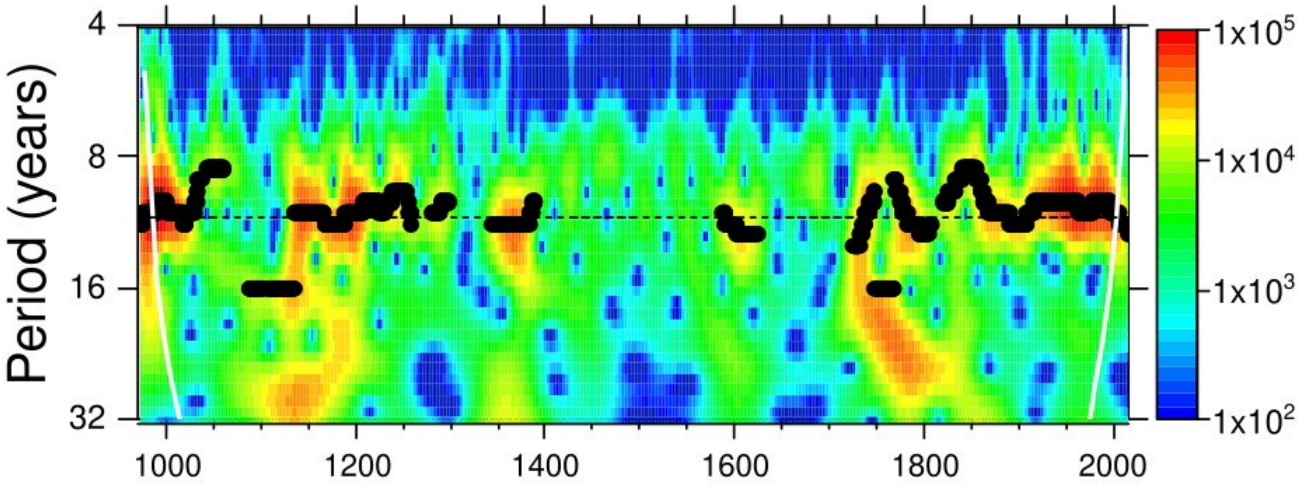

Figure 2. Wavelet power spectrum (Morlet basis, k=6) of the annual sunspot number reconstruction shown in Figure 1. Black dots denote the period corresponding to the maximum power in the range of 8—16 years at each year. The white lines indicate the cone of influence.

urements of the relative abundance of radiocarbon Δ^{14}C in tree rings for the period since 970 BC (Brehm et al., 2021). Using updated models and independently known archaeomagnetic reconstructions (e.g., Nilsson et al., 2014), these Δ^{14}C data were converted into sunspot numbers with the annual resolution (Usoskin et al., 2021), as shown in Figure 1. The new reconstruction includes 85 individual Schwabe cycles, about 50 of which are fairly or well resolved. This nearly triples the known statistic (~36 cycles) based on telescopic observations. The cycles greatly vary in amplitude covering the full range from low (three more grand minima of Oort, Wolf and Spörer are included in addition to the Maunder minimum, as indicated in Figure 1) to high activity levels. The average length of solar cycles is 10.8 years but vary significantly from cycle to cycle, as shown in Figure 2. The cycles cannot be reliably determined during grand minima but they are clearly distinguishable for the periods of moderate and high activity.

A basic analysis of the newly reconstructed solar cycles for the last millennium has been performed by Usoskin et al. (2021). This included the distribution of the cycle lengths that appears consistent with that of the direct sunspot data; confirmation of the grand-minimum state of solar activity as a special mode of the solar dynamo; and confirmation of the validity of the empirical Wadmeier's rule (strong cycles tend to rise faster) for larger statistic with high significance. The SCOSTEP scientific community is welcome to perform a more detailed investigation of the new dataset (available at http://cdsarc.u-strasbg.fr/viz-bin/cat/J/A+A/649/A141).

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Article 2:

Diagnosing Atmospheric Planetary-Scale Waves Through Multi-Station Approaches

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The mesosphere-lower-thermosphere (MLT) region is populated by intense global scale waves, but the relevant observations are sparse. Both balloons and spacecraft cannot routinely operate in MLT, and continuous observations are collected remotely by either optical instruments onboard satellites or radars on the ground. These observations have been broadly used to investigate MLT waves. Most of these investigations are based on single-station or -satellite approaches, and therefore are subject to inherent spatiotemporal ambiguities [e.g., For12, He11]. Single-station approaches cannot determine the horizontal scale of waves. To conquer this problem, we developed a series of multi-station approaches.

At first, we developed a dual-station approach to diagnose the zonal wavenumber of the underlying dominant wave, which is called the phase difference technique [PDT, see He18a]. The principle is sketched in Figure 1. Through cross-wavelet and Lomb-Scargle spectral analyses, we implemented the PDT on meteor wind collected from radar pairs at low-, mid-, and high-latitudes, as illustrated in Figure 2. The wavenumber could also be determined through optimization, using observations from an arbitrary number of radars. The wavenumbers estimated through PDT using different radar pairs were compared with those through the optimization using more than two radars, exhibiting consistency and evaluating the approaches [He20b, He21b]. According to the wavenumber estimations or prior knowledge, we assigned the most likely occurring wavenumbers and estimated their wave amplitudes through least-square regressions [He18a, He19, He21b]. In an evaluation, the least-square amplitudes exhibit quantitative consistency with the results using winds observed by the spacecraft ICON [He21b].

Compared with single-station approaches, multi-station approaches impose wavelength constraints and allow diagnosing global-scale waves more determi-

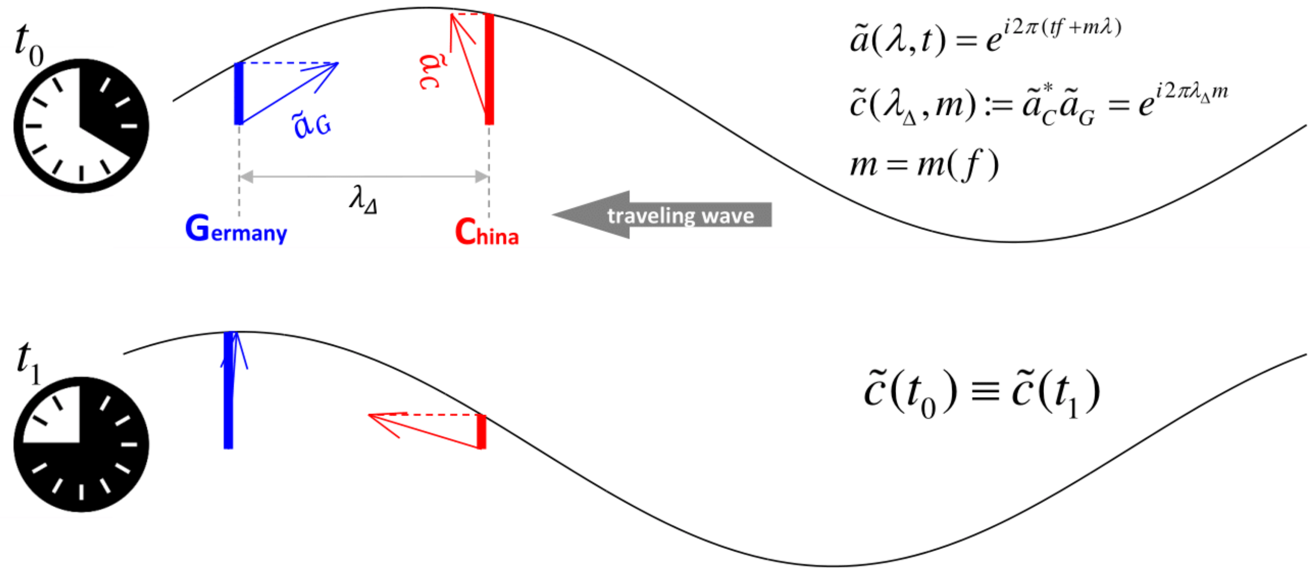

Figure 1. The principle of the phase difference technique [PDT, adjusted from the supporting information in He18a]. The oscillations generated by a plane wave are coherent between any locations on the wave's path. The phase difference between any two locations is constant, proportional to the spacing multiplied by the aligned wavenumber. Observational estimation of the phase difference provides a possibility for determining the aligned wavenumber. To realize the possibility, we utilized the single- and long-wave assumptions. The single-wave assumption requires that only one wave exists at a given frequency and instant. To facilitate this assumption, in different circumstances, we trade-off differently the frequency and time resolutions by modulating the spectral analysis window size. The long-wave assumption requires the wavelength is longer than twice the station spacing to satisfy Nyquist's theorem, which can be relaxed slightly by assuming the zonal wavelengths of the underlying waves are low order harmonics of 360° longitude.

Figure 2. Meteor radar configurations used for multi-station analyses. Dots with the same color denote stations that were paired for implementing the PDT. Crosses with the same color denote stations that were combined for implementing the optimization and least-square regression.

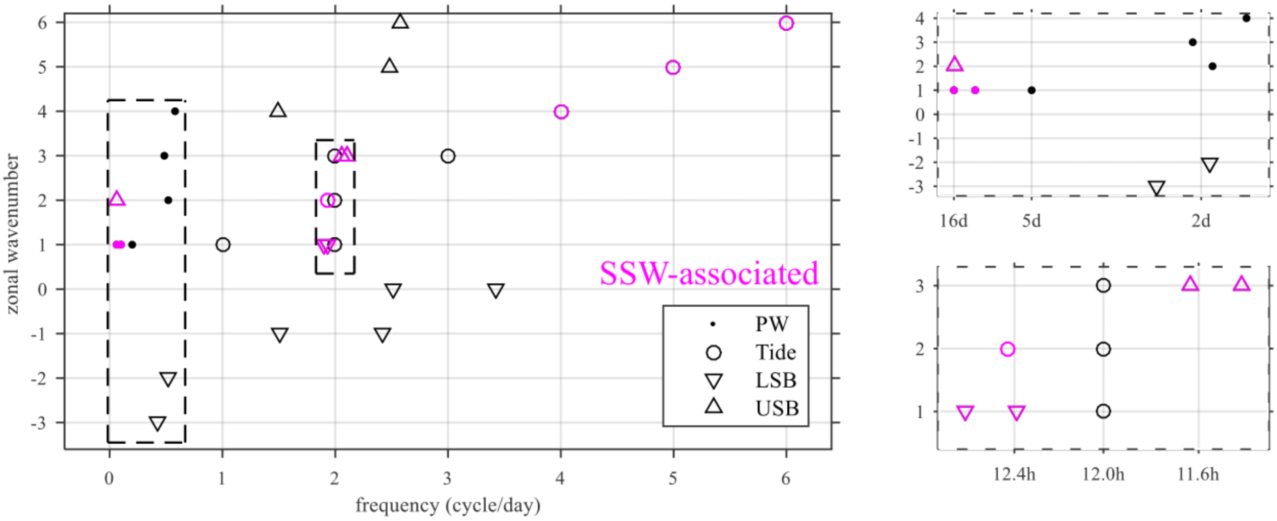

Figure 3. Waves diagnosed using multi-station approaches. Open circles denote lunar and solar tides. Solid dots denote planetary waves of Rossby normal modes and Rossby-gravity waves. Triangles denote secondary waves from nonlinear interactions between tides and planetary waves. Magenta symbols denote wave activities associated with SSWs. The regions in the dashed boxes in the left panel are zoomed into the right panels.

natively. We diagnosed a variety of novel wave activities, as summarized in Figure 3. In particular, many wave activities were found or detailed during sudden stratospheric warming events (SSWs), such as the enhancements of the Rossby normal modes [He20c], 12.4-hour lunar tide [M2, see He18a, He18b], upper and lower sidebands (USB and LSB) of interactions between planetary waves and tides [He19, He20a], interactions between traveling and stationary planetary waves (PWs), and 6-, 4.8-, and 4-hour migrating tides [He20b]. The enhanced migrating tides quench at the SSW central day [He20b]. We noted that, in single-station analyses, M2 estimation is contaminated by a 12.4-hour LSB arising from interactions between the 16-day wave and the 12-hour migrating tide [He18b]. The interactions also produce an 11.6-hour USB. These LSB and USB have been misinterpreted in some existing papers as two nonmigrating tides [SW1 and SW3, see He19]. Similar SW1-like LSB and SW3-like USB also arise from interactions of the 10-day wave, as observed during the Antarctic SSW in 2019 [He20a]. Furthermore, three months before this Antarctic SSW, we observed LSBs and USBs of interactions between two quasi-2-day Rossby-gravity waves and four solar migrating tides [He21a]. Besides these meteorological activities, the climatology of PWs and tides are also investigated using the multi-station approaches [He19, He21a]. At the moment, we are systematically extending our works by implementing the approaches on more meteor radar configurations and other ground-based observations, e.g., magnetometers [see For20], in broad ranges of frequency.

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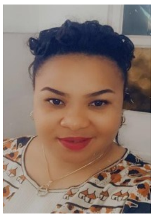
Highlight on Young Scientists 1:

Properties of High-Frequency Type II Radio Bursts and Their Relation to the Associated Coronal Mass Ejections



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Solar radio bursts are often early indicators of space weather events such as coronal mass ejections (CMEs). The high starting frequency implies shock formation closer to the solar surface, which has important ramifications for the analysis of particle acceleration near the Sun. In a recent study (Umuhire et al. 2021), we determined the properties of 40 high frequency (≥150 MHz) type II bursts that occurred in solar cycle 24 (2010 -2016) and the characteristics of the associated CMEs. We found the CME heliocentric distances at the onset time of metric type II bursts range from 1.16 to 1.90 solar radii (Rs). The study was also extended to 128 metric type II bursts to include lower-starting-frequency events for further analysis. The projected CME heights range from 1.15 to 2.85 Rs. The lower starting frequency correspond to shocks forming at larger heights.

Figure 1 shows an example of a high-starting-frequency type II burst observed by the Green Bank Solar Radio Bursts (GBSRB) spectrometer and its associated CME observed by STEREO-B/EUVI instruments. The fundamental starting frequency of the type II burst in the dynamic spectrum was 420 MHz at 17:35:00 UT. The ending frequency was 60 MHz at 17:40:30 UT. The event was associated with a flare, which occurred at N20E04 on the solar disk (see Cho et al., 2013, for details). The associated CME was at N20W90 in the STEREO-B Extreme Ultraviolet Imager (EUVI) field of view (FOV). The CME-driven shock was observed in EUV 64 seconds after the appearance of type II burst corresponding to a height of 1.22 Rs.

We used STEREO/COR1, EUVI and SDO/AIA images to identify CME shocks close to the first appearance time of type II bursts and to minimize projection effects. We determined CME heights using both the wave diameter and leading edge methods (Gopalswamy et al. 2013) for 117 of the 128 events for which the shock could be observed. We found that solar energetic particles are accelerated very close to the coronal base. Making use of type II bursts at different wavelengths, it was found that the power law between the starting frequency and CME heights are consistent with the rapid decline of density in the inner corona. The density drops from lower corona to the interplanetary medium (Gopalswamy et al., 2009).

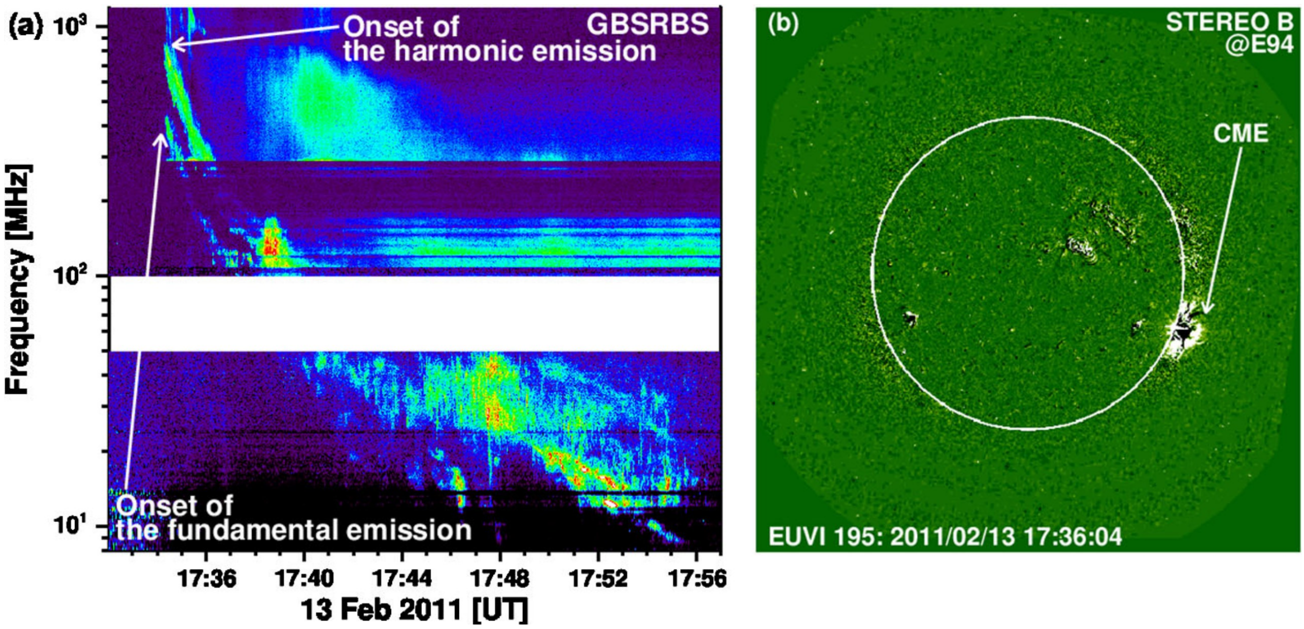

Figure 1. (a) A high-starting-frequency type II burst. The dynamic spectrum was obtained by the Green Bank Solar Radio Burst Spectrometer (GBSRBS). The fundamental starting frequency was 420 MHz at 17:35:00 UT. The high starting frequency implies the radio source closer to the solar surface, hence the associated CME originating in the lower corona. (b) STEREO-B/EUVI 195 Å difference image shown by white arrow. The time of the image in (b) is close to the starting time of the type II burst. STEREO-B was located at E94 at the time of the eruption.

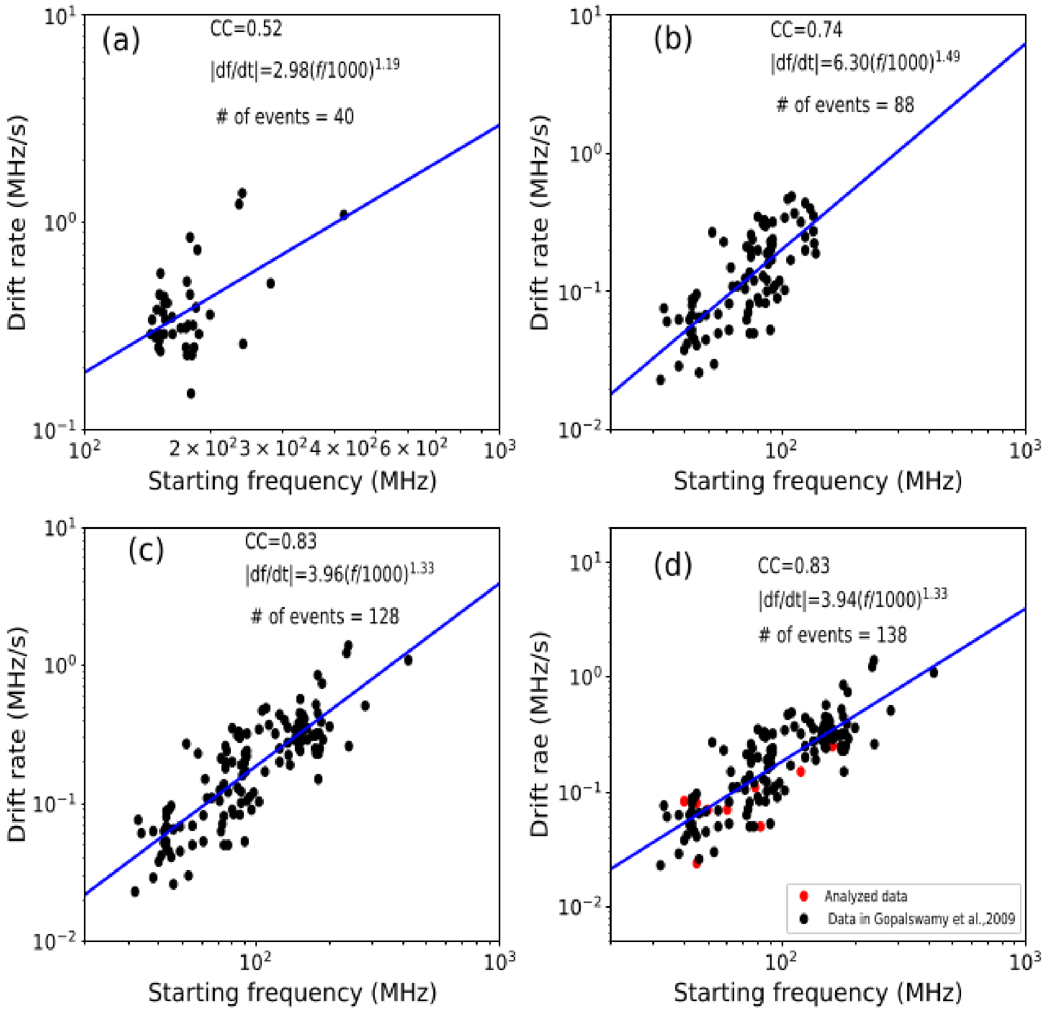

Figure 2. (a) Scatter plot between the starting frequency f and the drift rate df/dt (absolute value) for the 40 high starting frequency metric type II burst, the scatter plot represent a power law of the form | df/dt |⁓ $f^{ℇ}$ with _ = 1.19. (b) A similar plot for the 88 events with lower starting frequency, the power-law index (ℇ) increases to 1.49. The combined set of 128 type II bursts in Figure (c) gives ℇ= 1.33. (d) The superposition of 10 data points reported in Gopalswamy et al. (2009) with 128 data points analyzed in this study. ℇ remains 1.33.

We also investigated how the high-frequency type II bursts behave with respect to the power law nature of the drift rate spectrum of type II radio bursts (see Figure 2). From the observations, the power-law exponent is the smallest at the highest frequencies, consistent with the trend in the deviation from the universal drift rate spectrum.

Acknowledgements

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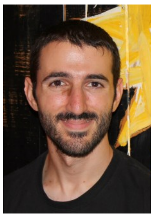
Umuhire, A.C., Gopalswamy, N., Uwamahoro, J., Akiyama, S., Yashiro, S., Ma˙kela¨, P., 2021. Properties of High-Frequency Type II Radio Bursts and Their Relation to the Associated Coronal Mass Ejections. Sol. Phys. 296 (1), 27.

Highlight on Young Scientists 2:

Analysing CaII K Observations for Reconstructions of Past Solar Irradiance Variations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The Sun provides almost all of the external energy to Earth, bearing the potential to affect Earth's climate. Measurements of the solar radiative energy flux at the top of Earth's atmosphere (solar irradiance) began in 1978. Climate studies require data for earlier periods, which are provided by models.

Such models reconstruct past solar irradiance by typically relying on sunspot observations, the longest solar data available since 1600's. Such observations, however, miss the bright magnetic features, faculae and network, thought to be responsible for the secular irradiance changes.

Information about faculae can be derived from full-disc observations in the singly-ionized Calcium line, CaII K. Despite CaII K observations are among the oldest systematic solar observations (since 1892), they have been largely unexplored for studies of long-term solar variability.

To take the full advantage of the potential of these data, we have compiled the most comprehensive database of over 300,000 CaII K observations from 38 observatories (Chatzistergos et al. 2020). We developed an automatic procedure to correct for various artefacts in the images and account for the non-linear response of the photographic emulsion (Fig. 1). We have also determined the relation between the CaII K brightness and the magnetic field strength so to convert CaII K observations to magnetograms (Chatzistergos et al. 2019) and constructed a plage-area composite record.

As a next step, we have adapted the SATIRE (Krivova et al. 2003) model to use magnetograms reconstructed from CaII K images (Chatzistergos et al. 2021). We have reconstructed TSI variations from various CaII K archives over the period when direct TSI measurements exist (Fig. 2) and showed that such data can be used to recover past irradiance variations quite accurately. This paves the way for using historical photographic CaII K archives for more accurate reconstructions of the irradiance variations back to 1892.

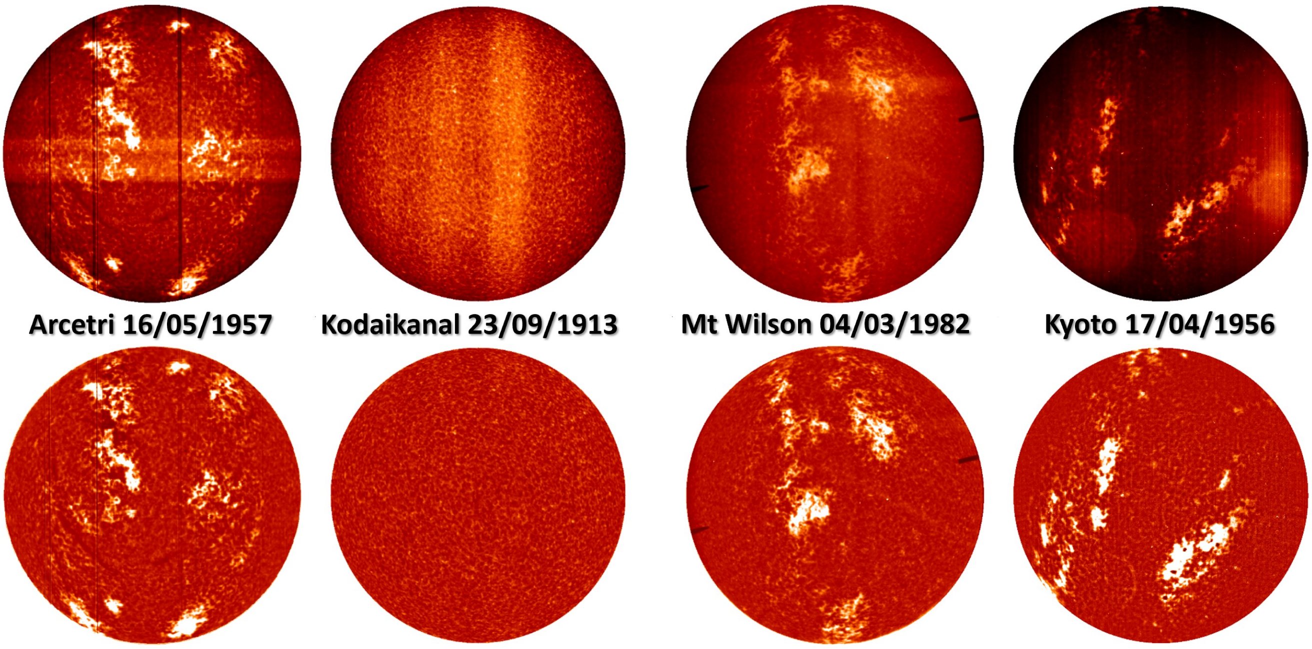

Figure 1. Exemplary observations from the Arcetri, Kodaikanal, Mt Wilson, and Kyoto sites. Shown are the raw positive observations (top) and the images processed and calibrated with our procedures (bottom).

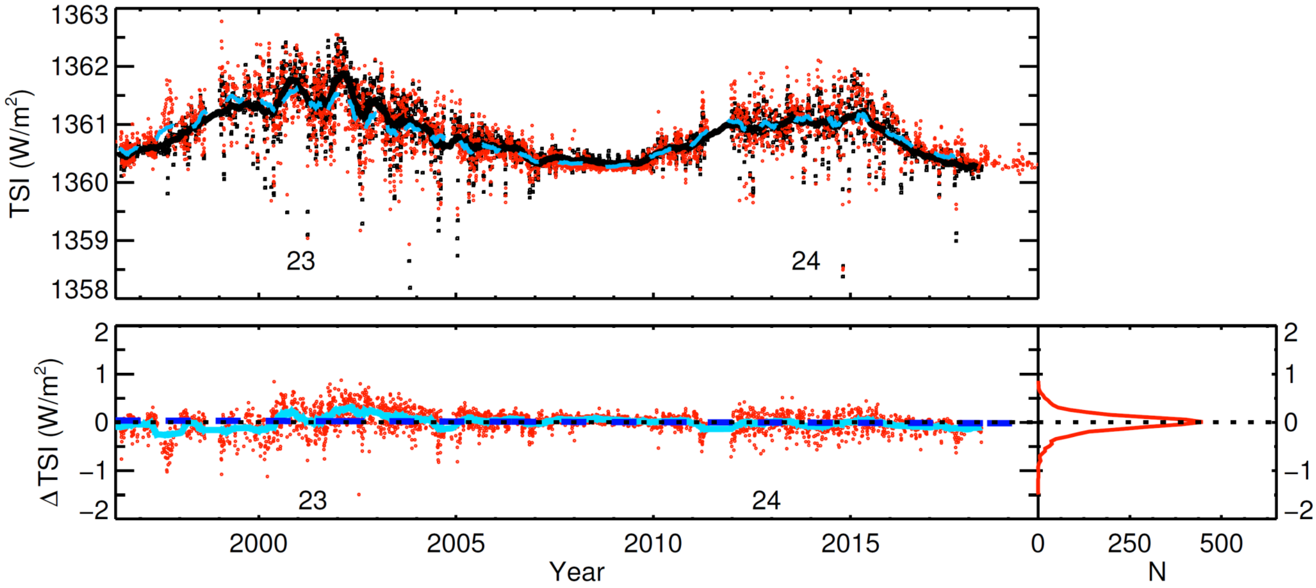

Figure 2. Top: TSI variations reconstructed from Rome/PSPT Ca II K observations (red for daily and ciel for 81-day running mean). Also shown are the values from the PMOD TSI composite (black). Bottom left: Residuals between our reconstruction of TSI and the PMOD TSI composite (red for daily and ciel for 81-day running mean). The dashed blue line is a linear fit to the residuals, while the black dotted line is a line with no trend. Bottom right: distribution of residuals in bins of 0.05 Wm^{-2}.

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Meeting Report 1:

The 1st Summer School on Space Research, Technology & Applications for Young Scientists and PhD Students

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The first edition of the summer school on Space research, technology and applications was held in the National Astronomical Observatory – Rozhen, Bulgaria from 5th to 11th July 2021 in a hybrid mode. Over 42 (14 on-site and 28 online) participants from 20 different countries attended the school. A versatile coverage of topics from theoretical astrophysics to engineering and computing was offered to the students. The program was organized as morning online lectures and afternoon on-site practice sessions and was structured in three main topics: Fundamental research (Theoretical astrophysics and cosmology; Sun and space weather); Aerospace technologies; Space-related methods and applications (Earth observations; Machine learning). Five practice groups were formed: Atmospheric measurements via drone; Astrophotography; Forecasting of CME effects; Machine learning; Sensors. At the end of the school, each team presented the results from their practice work led by an experienced mentor and on-site assistant. In addition, each participant gave a short overview on their PhD topic during a dedicated PhD session.

The summer school received financial support from the foundation America for Bulgaria, SCOSTEP, Karoll foundation and British Council and was held under the auspices of the Ministry of Economy of Bulgaria. Assistance was provided by the Institute of Astronomy - Bulgarian Academy of Sciences, Bulgarian Science Fund, and UK science & Innovation Network.

The initiative is planned to continue in future as an annual event in Bulgaria on space-related topics and be open for PhD students and young scientists from all around the globe. More details, open-access lectures, presentations and videos can be found at the summer school web-site: https://bulgarianspace.online/space-schoolbg-2021/ .

Figures. Group photos of the on-site participants, organizers and youngsters in front of the 2-m telescope and its dome in NAO-Rozhen.

Meeting Report 2:

i4s – First Iberian Space Science Summer School


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The i4s school 2021 (https://www.i4s-iberian-space-science-summer-school.com/) was held between July 26th and July 30th of 2021 on-line due to the COVID19 pandemics using Zoom and Slack web services. The students of the i4s were almost equally distributed between the eastern (China, India, and Middle Asia), Euro-African and western (N. and S. Americas).

Nine lectures covered different space weather topics: The Sun; Solar wind and interplanetary medium; Magnetosphere; Ionosphere and Upper Atmosphere; Lower atmosphere and ground effects; Climate Change. All lectures were recorded, and the videos and the slides were uploaded to the i4s Google Drive with password-protected access for school students, Lecturers and Mentors and lectures' attendees.

The school was organized by IA (Portugal) and SWE-UAH (Spain), with the support of ISWI and SCOSTEP, being in line with their aims in providing training in the domain of Space Science.

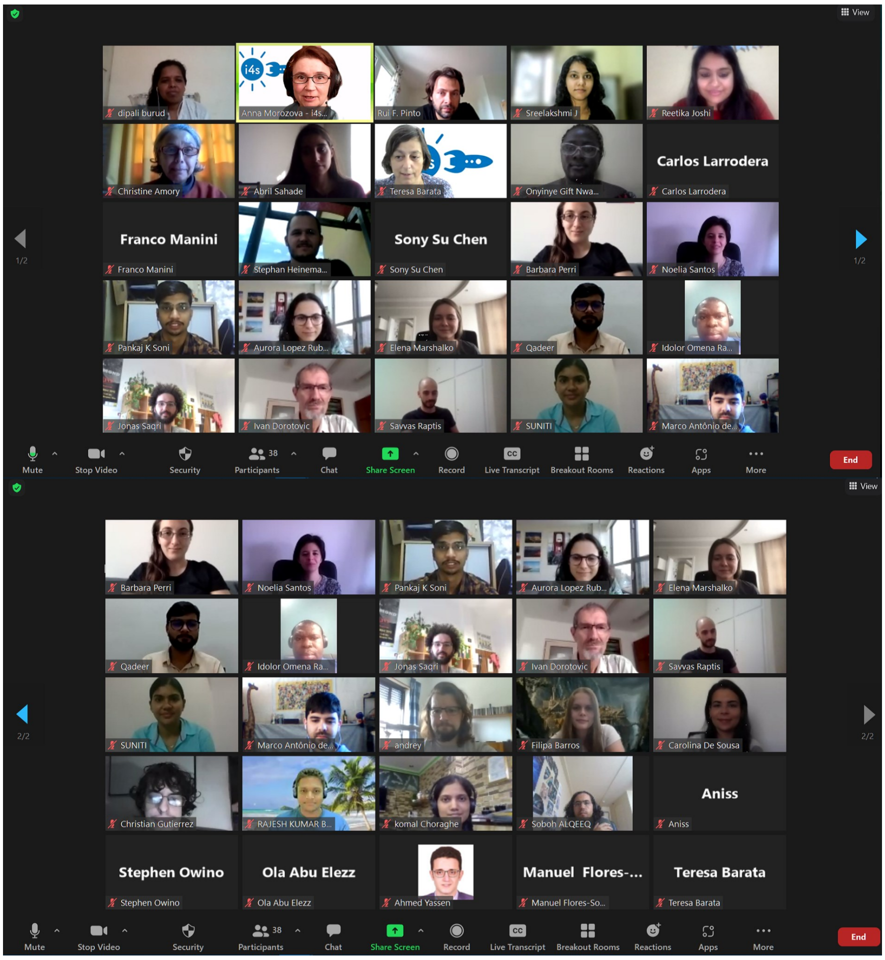

Figure. Zoom Group Photo of the participants of the i4s school 2021

Upcoming meetings related to SCOSTEP

Conference	Date	Location	Contact Information
The 30th IUPAP General Assembly	Oct. 20-22, 2021	Beijing, China	http://iupap-ga2020.cps-net.org.cn/
AGU Fall Meeting 2021	Dec. 13-17, 2021	New Orleans, LA, USA	https://www.agu.org/fall-meeting
SCOSTEP's 15th Quadrennial Solar-Terrestrial Physics Symposium (STP-15)	Feb. 21-25, 2022	Alibag, India	https://www.stp15.in/
EGU General Assembly 2022	Apr. 3-8, 2022	Vienna, Austria	https://www.egu22.eu/
COSPAR 2022	Jul. 16-24, 2022	Athens, Greece	http://ww.cosparathens2022.org/
AOGS 2022	Aug. 14-19, 2022	Melbourne, Australia	https://www.asiaoceania.org/society/public.asp?page=home.asp
SUMMER SPACE WEATHER SCHOOL - Physics and use of tools	In October, 2022	Houphouët Boigny University, Abidjan, Côte d'Ivoire	
AGU Fall Meeting 2022	Dec. 12-16, 2022	Chicago, IL, USA	https://www.agu.org/fall-meeting
IUGG 2023	In July, 2023	Berlin, Germany	https://www.iugg2023berlin.org/
AGU Fall Meeting 2023	Dec. 11-15, 2023	San Francisco, CA, USA	https://www.agu.org/fall-meeting

Please send the information of upcoming meetings to the newsletter editors.

Announcement 1:

VarSITI Review Papers Are Published in the Open Access PEPS Journal


Kazuo
Shiokawa


Katya
Georgieva


Nat
Gopalswamy

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(Associate Editors VarSITI Special Issue of Progress in Earth and Planetary Science)

The Variability of the Sun and Its Terrestrial Impact (VarSITI) was the SCOSTEP's 5-year international program during 2014-2018. Four scientific projects were carried out under the VarSITI program: (1) Solar Evolution and Extrema (SEE), (2) International Study of Earth-Affecting Solar Transients (ISEST/MiniMax24), (3) Specification and Prediction of the Coupled Inner-Magnetospheric Environment (SPeCIMEN), and (4) Role Of the Sun and the Middle atmosphere / thermosphere / ionosphere In Climate (ROSMIC). Five review papers that highlight the achievements of the VarSITI program have now been published in a special issue of the Progress in Earth and Planetary Science (PEPS, open access) . The papers are: https://www.springeropen.com/collections/varsiti.

1. **VarSITI:** K. Shiokawa and K. Georgieva, A review of the SCOSTEP's 5-year scientific program VarSITI—Variability of the Sun and Its Terrestrial Impact, PEPS, 8:21, 2021.

   https://progearthplanetsci.springeropen.com/articles/10.1186/s40645-021-00410-1

2. **SEE:** D. Nandy, P. C. H. Martens, V. Obridko, S. Dash and K. Georgieva, Solar evolution and extrema: current state of understanding of long-term solar variability and its planetary impacts, PEPS, 8:40, 2021.

   https://progearthplanetsci.springeropen.com/articles/10.1186/s40645-021-00430-x

3. **ISEST/MiniMax24:** J. Zhang, M. Temmer, N. Gopalswamy, O. Malandraki, N.V. Nitta, S. Patsourakos, F. Shen, B. Vršnak, Y.-M. Wang, D. Webb, M. I. Desai, K. Dissauer, N. Dresing, M. Dumbović, X.-S. Feng, S. G. Heinemann, M. Laurenza, N. Lugaz, and B. Zhuang, Earth-affecting solar transients: a review of progresses in solar cycle 24, PEPS, 8:56, 2021.

   https://progearthplanetsci.springeropen.com/articles/10.1186/s40645-021-00426-7

4. **SPeCIMEN:** S. Kanekal and Y. Miyoshi, Dynamics of the terrestrial radiation belts: a review of recent results during the VarSITI (Variability of the Sun and Its Terrestrial Impact) era, 2014–2018, PEPS, 8:35, 2021.

   https://progearthplanetsci.springeropen.com/articles/10.1186/s40645-021-00413-y

5. **ROSMIC:** W. Ward, W. Ward, A. Seppälä, E. Yiğit, T. Nakamura, C. Stolle, J. Laštovička, T. N. Woods, Y. Tomikawa, F.-J. Lübken, S. C. Solomon, D. R. Marsh, B. Funke, and D. Pallamraju, Role Of the Sun and the Middle atmosphere/thermosphere/ionosphere In Climate (ROSMIC): a retrospective and prospective view, PEPS, 8:47, 2021.

   https://progearthplanetsci.springeropen.com/articles/10.1186/s40645-021-00433-8

The success of the VARSITI program was possible due to the invaluable contributions from different quarters: the International Space Science Institute (ISSI), the organizers of various symposia and workshops, the funding agencies that supported meeting and research activities, and above all the more than 1,000 scientists who focused their research efforts on VarSITI.

The purpose of the The purpose of the SCOSTEP/PRESTO newsletter is to promote communication among scientists related to solar-terrestrial physics and the SCOSTEP's PRESTO program.

The editors would like to ask you to submit the following articles to the SCOSTEP/PRESTO newsletter.

Our newsletter has five categories of the articles:

1. Articles— Each article has a maximum of 500 words length and four figures/photos (at least two figures/photos).
   With the writer's approval, the small face photo will be also added.
   On campaign, ground observations, satellite observations, modeling, etc.
2. Meeting reports—Each meeting report has a maximum of 150 words length and one photo from the meeting.
   With the writer's approval, the small face photo will be also added.
   On workshop/conference/ symposium report related to SCOSTEP/PRESTO
3. Highlights on young scientists— Each highlight has a maximum of 300 words length and two figures.
   With the writer's approval, the small face photo will be also added.
   On the young scientist's own work related to SCOSTEP/PRESTO
4. Announcement— Each announcement has a maximum of 200 words length.
   Announcements of campaign, workshop, etc.
5. Meeting schedule

Category 3 (Highlights on young scientists) helps both young scientists and SCOSTEP/PRESTO members to know each other. Please contact the editors if you know any recommended young scientists who are willing to write an article on this category.

TO SUBMIT AN ARTICLE

Articles/figures/photos can be emailed to the Newsletter Secretary, Ms. Mai Asakura (asakura_at_isee.nagoya-u.ac.jp). If you have any questions or problem, please do not hesitate to ask us.

SUBSCRIPTION - SCOSTEP MAILING LIST

The PDF version of the SCOSTEP/PRESTO Newsletter is distributed through the SCOSTEP-all mailing list. If you want to be included in the mailing list to receive future information of SCOSTEP/PRESTO, please send e-mail to "patricia.doherty_at_bc.edu" or "sean.oconnell.2 at bc.edu" (replace "_at_" by "@") with your name, affiliation, and topic of interest to be included.

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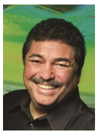

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