VLF/ELF Remote Sensing of Ionospheres and Magnetospheres (VERSIM)

Annual newsletter of VERSIM: a joint IAGA/URSI working group
Editor: Andrei Demekhov No. 35, December 2020

Dear VERSIM friends and colleagues,

Near the very end of the year 2020, I would like to bring our annual newsletter to your kind attention. This is my first full year as a IAGA co-chair of our VERSIM working group, after Prof. Jacob Bortnik stepped down after his remarkable 6-year service for the period of 2013 to 2019. Recall that the previous co-chair Prof. Craig Rodger had served for 11 years, i.e., for the entire solar cycle. I would like to express my great thanks to Jacob and Craig for their continuing support of VERSIM in general and friendly advice to me as a co-chair. Note that next year our URSI co-chair Mark Clilverd is willing to step down, so we will need a new URSI co-chair who would be as helpful as Mark in all our activities.

Most or even all of us have been affected in one or many respects by the new Covid-19 pandemic, that not only prevented us from meeting in person with colleagues from other countries and even cities but also threatened our health and lives. Some of us may have lost colleagues, friends, and relatives which I note with great sorrow. Nevertheless our community has been quite active and, as shown in the next pages, we have been performing very interesting research and have obtained very exciting new results.

We have had a very historical VERSIM meeting this November: the first online conference of our community (http://pcwave.rish.kyoto-u.ac.jp/versim/). Many of us were concerned about the lost opportunity of personal discussions, but the organizers from the Kyoto University led by Prof. Yoshiharu Omura have been able to provide, at least partly, even this vital aspect of every meeting due to the use of Spatialchat discussion rooms. We even had a sakura blossom, though only as a picture, reminding us about the originally planned spring time of the meeting. Let me thank once again Professor Omura and his colleagues for their tremendous effort in organizing and running this remarkable event so wonderfully. As it happens, there has been a blessing in disguise, and we have got an extremely high number of participants from many countries who presented excellent reports. As a result of competition between young participants, Ms. Man Hua from Wuhan University (China) has been nominated for a IAGA Early Carreer Award.

I hope you will read this newsletter with interest and perhaps learn something new about a variety of activities and results of our community, often due to productive collaborations.

Please take care and have a happy, healthy, and successful 2021!

Andrei Demekhov,
IAGA co-chair

Mark Clilverd,
URSI co-chair

BELGIUM: Report prepared by Dr. Fabien Darrouzet (Fabien.Darrouzet@aeronomie.be), Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium, http://awda.aeronomie.be/

We continue our project to detect whistler waves with VLF measurements. A VLF antenna has been installed in October 2010 in Humain, Belgium (Lat~50.11°N, Long~5.15°E), in order to detect whistlers and determine electron densities along propagation paths. The VLF antenna is made of two perpendicular magnetic loops, oriented North-South and East-West and with an area of approximately 50 m^2 each. We have re-done a statistical analysis of all the data from 2011 but considering only 1 antenna (East-West direction) because the signal is much less noisy. We obtained much more whistlers than previously, which allowed a better statistical analysis (see Figure).

We have installed in January-February 2016 another VLF antenna at the Belgian Antarctic station Princess Elisabeth (Lat~71.57°S, Long~23.20°E), with the help of Dr. J. Lichtenberger (Hungary). This antenna is composed of two search coils, without a mast in order to withstand the weather at such latitudes. Severe electromagnetic perturbations observed since 2017 have been removed during the last season (January-February 2020) and a new team is actually (November-December 2020) at the station to check the instrument, fix some issues and collect all the data.

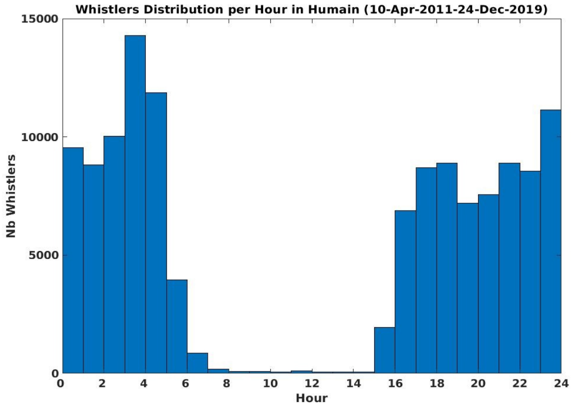
Those antennas are part of AWDAnet, the Automatic Whistler Detector and Analyzer system's network. This network covers low, mid and high magnetic latitudes including conjugate locations. It has been initiated by Dr. J. Lichtenberger (Hungary).

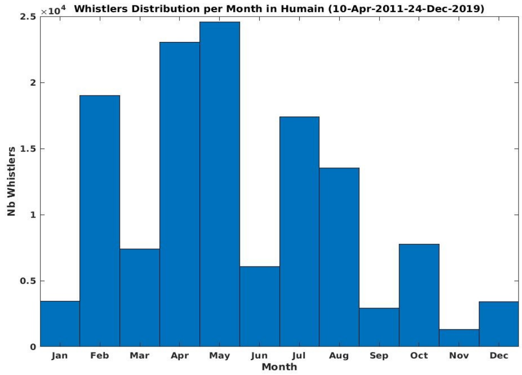
CZECHIA: Report prepared by Ivana Kolmasova (iko@ufa.cas.cz), Frantisek Nemec (frantisek.nemec@gmail.com), and Ondrej Santolik (os@ufa.cas.cz), Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague and Charles University, Prague.

Our group at the Department of Space Physics, Institute of Atmospheric Physics of the Czech Academy of Sciences and at the Faculty of Mathematics and Physics of the Charles University continued to investigate inner magnetospheric electromagnetic waves using ground-based experiments and spacecraft measurements. Examples of our results obtained in 2020 are given below.

We analyzed the fine harmonic structure of EN emissions with a quasiperiodic (QP) modulation of their wave intensity [1]. We found that the harmonic frequency spacings of most events were between about 2 and 6 Hz. Assuming that the frequency spacing corresponds to the proton cyclotron frequency in the source region located at the geomagnetic equator, these frequency spacings can be used to calculate radial distances of the sources. The obtained distribution of source radial distances was rather broad, ranging from about 3.5 to 6 R_E. The fine harmonic structure further allowed us to identify events for which the spacecraft passed through the source region. No QP modulation of the ambient magnetic field and/or plasma density was observed, and we thus hypothesized that the QP modulation of the wave intensity is due to periodic variations of the proton distribution function. However, we were not able to confirm this hypothesis experimentally. An example of one of the 72 analyzed events is shown in Figure.

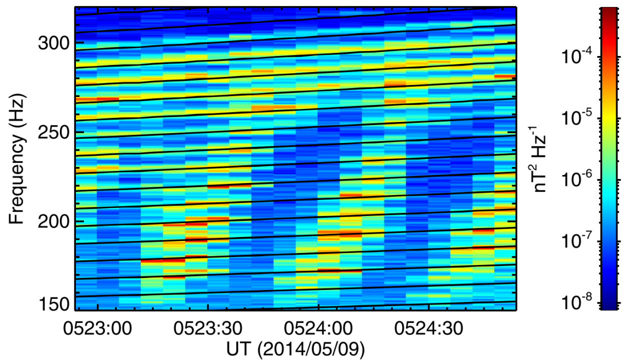
We also tried to explain differences in the occurrence rates of whistler mode QP emissions observed by the Van Allen Probes in the equatorial region at larger radial distances and by the low-altitude DEMETER spacecraft [2]. We





Statistical analysis of whistlers detected in Humain (Belgium) from April 2011 to December 2019: Distribution of whistlers (East-West antenna) as a function of (left) local time and (right) month.

explained the apparent inconsistency by considering a nondipolar Earth's magnetic field and significant background wave intensities which prevent the QP events from being identified in DEMETER data. Comparison with the Kannuslehto VLF station showed that Van Allen Probes consistently observed events at lower L shells, with the event occurrence primarily inside of the plasmasphere [3].



An example of frequency-time spectrogram of power spectral density of magnetic field fluctuations measured by the Van Allen Probes B on 9 May 2014 between 05:22:54 and 05:24:54 UT showing an EN event with the modulated wave intensity. The black curves show the harmonics of the proton cyclotron frequency at the observation point based on in situ magnetic field measurements.

Based on the optical observations of elves (Emission of Light and Very Low Frequency perturbations due to Electromagnetic Pulse Sources - a type of transient luminous events), we used narrowband measurements of VLF transmitters as well as broadband VLF measurements of lightning atmospherics to indicate extensive ionospheric disturbances as manifestations of lightning return strokes associated with elves [4].

We also examined a simultaneous observation of electromagnetic ion cyclotron (EMIC) wave activity by the RBSP-B and Arase satellites in conjunction with ground-based observations of energetic electron precipitation (EEP) by a subionospheric VLF network and investigated the ability of EMIC waves to drive EEP into the Earth's atmosphere [5]. We determined an approximate longitudinal extent and drift rate of the EMIC source region using a combination of in situ spacecraft and ground-based measurements. We presented a simple procedure to calculate the extent of an EEP-driving EMIC source region from the EEP signature in ground-based VLF measurements.

We used the nonlinear growth theory of chorus emissions to develop a model of the chorus subpacket formation [6]. The model assumes that the resonant current, which is released from the source to the upstream region, radiates a new whistler mode wave with a slightly increased frequency, which triggers a new chorus subpacket.

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FIJI: Report prepared by Sushil Kumar (kumar_su@usp.ac.fj), The University of the South Pacific (USP), Suva, Fiji.

Our group continues participating in the World-Wide Lightning Location Network (WWLLN) since our joining in 2003. We continue recording narrowband very low frequency (VLF) signals of six transmitters using the SoftPAL data acquisition system located at Physics, USP, Suva (18.15°S, 178.45°E) which was started in the year 2006. The narrowband VLF recording with two more SoftPAL stations in Apia, Samoa, and Port

Villa, Vanuatu, where our university has its regional campuses, was also made.

The amplitude perturbations on the VLF transmitter signals observed during tropical cyclones (TCs), TC Pam (2015) and TC Winston (2016) were analyzed. The sea surface temperature (SST) and upper ocean heat content (OHC) have been explored along the track of two tropical cyclones (TCs), TC Pam (2015) and TC Winston (2016). These TCs severely affected the islands of Vanuatu and Fiji, in the South Pacific Region (8°–30°S, 140°E–170°W). The SST decreased by as much as 5.4°C along the tracks of the TCs with most cooling occurring to the left of the TCs tracks relative to TCs motion. SST cooling of 1-5°C has generally been observed during both the forced and relaxation stages of TC passage.

The diurnal variations in the phase and amplitude of NWC, NPM, and NLK very low frequency (VLF) transmissions received at Suva, Fiji, have been modeled using the Long Wave Propagation Capability (LWPC V2.1) code to determine the ionospheric D region parameters, H' (reference height) and β (rate of increase of electron density with height), for different daytime and nighttime conditions along the transmitter-receiver great circle paths (TRGCPs). Measured VLF signal amplitude and phase show explicit variation over the day and nighttime along the TRGCP, also revealing amplitude minima and phase steps during sunrise and sunset as the day/night terminator traverses the TRGCP. While the daytime signal strength is reasonably smooth, at nighttime, the signal exhibits a great deal of variability. For three signal paths, the mean daytime H' and β were found to be 70.7 km and 0.40 km^{-1}, respectively, while nighttime mean values of these parameters were found to be 84.2 km and 0.68 km^{-1}, respectively. The temporal and day-to-day variability of the nighttime D region parameters shows that H' and β ranges in between 83.0 – 85.0 km and 0.58 – 0.80 km^{-1}, respectively.

Ionospheric observations are being continued with the new Global Navigation Satellite Systems station for Ionospheric Monitoring and Precise Point Positioning (PPP) Research under normal and space weather conditions, installed under an MoU between School of Engineering and Physics (SEP), USP, and the School of Electronics and Information Engineering (SEIE), Beihang University, China. Please visit for details: http://www.usp.ac.fj/news/story.php?id=3219

For other details please visit USP's electronic research repository http://repository.usp.ac.fj/ and research our research group web http://sep.fste.usp.ac.fj/index.php?id=15705

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FINLAND: Report prepared by Dr. Jyrki Manninen (Jyrki.Manninen@oulu.fi), Sodankylä Geophysical Observatory, University of Oulu, Finland, www.sgo.fi

Winter 2019-2020 ELF-VLF campaign started on 4 September 2019 and ended on 24 April 2020. The campaign had no long breaks at all. This autumn we started our campaign just on 14 September 2020, because we had to change our electric generator. Current plan is to continue recordings till the end of April.

The quick-look plots (24-h, 1-h, and 1-min) are available at http://www.sgo.fi/vlf/. During the campaign, new plots are updated within a few days after recording. The frequency range of quick-look plots is from 0 to 16 kHz, while the data contain the range from 0 to 39 kHz. Upper band is available if someone is interested in.

It should be reminded that now all quick-look plots, what are in our server, have been analysed with both PLHR and sferics filters. If you are interested in our data, just contact Jyrki.Manninen@oulu.fi. We can make a vast amount of different kind of analysis for our ELF-VLF data.

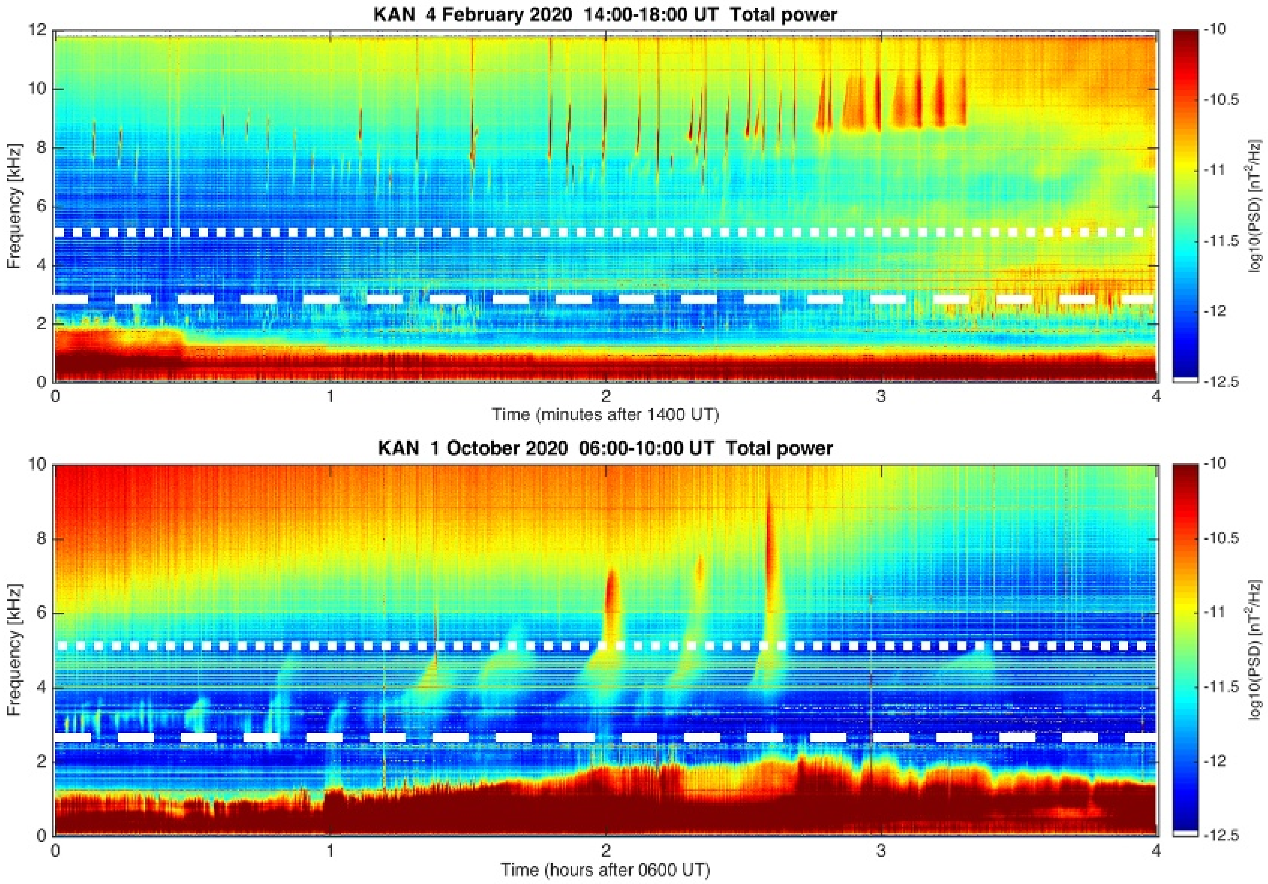
Due to Covid-19 pandemic our colleagues have not been able to visit SGO during the year. However, the number of peer-reviewed papers during this year was reasonably good, because of 10 published papers listed in references, and 3 more are under reviewing process. Also a lot of different activities have been planned for after-pandemic era.

MSc. Liliana Macotela had her PhD thesis dissertation on 23 April 2020 in Sodankylä. The opponent was Prof. Paul Cannon from Birmingham, UK, and custos (chairperson of the event) was Prof. Eija Tanskanen from SGO. The event was organised so that Liliana was physically in SGO lecture room with 3 other persons, custos was chairing remotely from Helsinki and the opponent was asking questions remotely from Birmingham. The event had international audience of more than 60 listeners from different parts of the world. Everything went smoothly, and Liliana got the highest grades from pre-examiners and the opponent.

In October 2020 she got a postdoc position at the Leibniz Institute for Atmospheric Physic, Kühlungsborn, Germany. At the same time, she also forwarded her VERSIM JC responsibilities to a new person.

Some new results have been shown in 9th VERSIM Workshop in November 2020.

10th VERSIM Workshop will be organised by Sodankylä Geophysical Observatory in Sodankylä area in September 2022. There is also an idea to organise 2-5 days VERSIM school just before the Workshop. More information will be announced during 2021.



Two 4-hour examples of high-frequency events. Upper panel presents afternoon event on 4 Feb 2020 in frequency range of 0-12 kHz. Lower panel shows morning event 1 Oct 2020 in frequency range of 0-10 kHz. Dashed white lines show 5.2 kHz and 2.6 kHz (f_{Heq} and 0.5 f_{Heq} for L=5.5).

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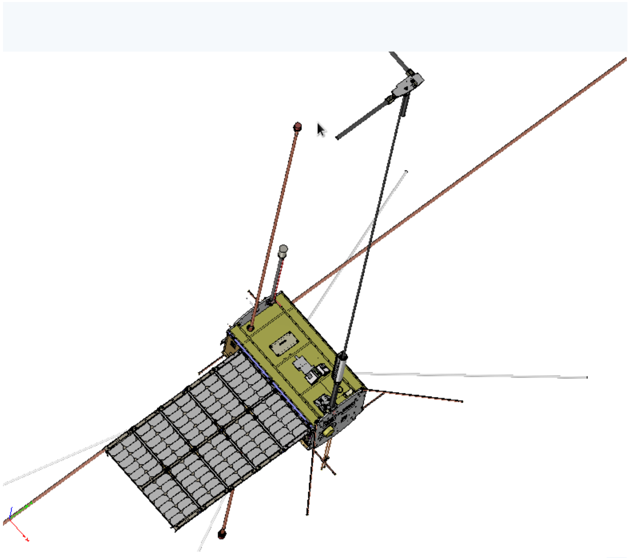
There were also several oral and poster presentations in 2020.

HUNGARY: Report prepared by Prof. János Lichtenberger(lityi@sas.elte.hu), Space Research Group, Department of Geophysics and Space Sciences, Eötvös University, Budapest, Hungary

Our group continued the theoretical modeling and model-calculations of monochromatic and transient (Ultra Wide Band) electromagnetic signals and are seeking a solution of the electromagnetic wave propagation in general relativistic situations (coupled solution of the Maxwell and Einstein equations).



The 3D CAD model of Trabant microsatellite

This year we continued the preparation of Trabant mission with Russian partners to study the (equatorial) ionosphere and space weather. The mission will consists two identical microsatellites (m=~75kg). The satellites will be released by a Progress cargo rocket to a ~500km orbit in the same plane as of the ISS (51.2 degree inclination). We have completed the Breadboard Models of SAS3-T ULF-ELF-VLF wave instrument, the high speed X-band telemetry system and the On-board Computer and started the development of the Engineering Qualification Models. The two microsatellites will be injected into orbit in 2023-24.

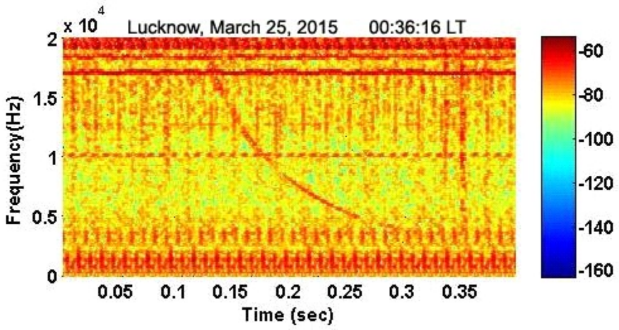
We have just started a European Space Agency project to develop plasmaspheric products for ESA Space Situational Awareness Programme using densities derived from AWDANet VLF and EMMA magnetometer network data as well as in-situ density data. The products to be developed include statistical and data assimilative plasmasphere and plasmapause models.

Reference:

Del Corpo, A., Vellante, M., Heilig, B., Pietropaolo, E., Reda, J., & Lichtenberger, J. (2020). An empirical model for the dayside magnetospheric plasma mass density derived from EMMA magnetometer network observations. Journal of Geophysical Research: Space Physics, 125, e2019JA027381. https://doi.org/10.1029/2019JA027381

INDIA: Report prepared by Prof. Ashok Kumar Singh (aksphys@gmail.com), Department of Physics, University of Lucknow, Lucknow, India

Large currents along the magnetic field transmit stresses between ionosphere and magnetosphere. If the electrons carrying such currents have high enough drift velocity, waves are generated. A wave is a disturbance that propagates through space and time, usually with transference of energy and play major part in the Earth's magnetospheric dynamics. Lightning discharges produce broadband electromagnetic impulses that travel in the Earth-ionosphere cavity. This guided propagation of waves occurs with low attenuation rates (2-3 dB/1000 km) at ELF/VLF frequencies.



Spectrogram of whistlers recorded at Lucknow (India) on March 25, 2015

We are continuously involved in VLF/ELF studies. We have observed some very good quality whistlers at our ground based station Lucknow (Geom. Lat. 17.60 N; Geom. Lon. 154.50 E; L = 1.10), India. These whistlers having high dispersion (~40 $sec^{1/2}$) have travelled in the magnetosphere (L~3)) and can be used in remote sensing of upper atmosphere. We have studied the intensity variation for individual whistlers which show the decrement in intensity. At 10 kHz intensity of whistlers increases may be because low absorption coefficient in night hours.

With increase in number of observing stations world-wide and with more instrumentation and continuous data we can have more precise information about medium parameters. Most ground based observations in the VLF band are dominated by the strong impulsive signals radiated by lightning discharges.

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NEW ZEALAND: Report prepared by Dr. Craig J. Rodger (craig.rodger@otago.ac.nz), University of Otago, Dunedin, NZ; http://www.physics.otago.ac.nz/nx/space/space-physics-home.html

I am sure like most of the international community, 2020 has been a very strange year, and also a very difficult year. As far as I can tell, we are "lucky" relative to a lot of the world - New Zealand's distance from most nations gave us more time to prepare and react, but also the leadership here acted "hard and early", following scientific and professional advice. So after a couple of months of hard lockdown from mid-March to May, we have been able to return to work with relatively light restrictions and COVID essentially eliminated inside the countries Boarders.

On the negative side, this means we have not been able to travel the world, or host our colleagues here in Dunedin. I am grateful that Mark Clilverd came to see us in late January-early February, before that became impossible. We also had some people "come home" at the start of lockdown - Aaron Hendry is now back working in the Otago group, and former student Harriet George (now undertaking a PhD in Helsinki), spent lockdown in Dunedin. She was able to join us for space physics coffee once the restrictions were eased, before returning to Finland.

In the last month or so we have joined online meetings, particularly VERSIM and Fall AGU. While they are no replacement for in person contact, it was wonderful to see everyone again. I do hope we will have the chance to meet in person sometime in 2021 (or 2022!). The group also had good news, "winning" New Zealand research funding to undertake more work on Space Weather impacts on energy networks, like power grids and gas pipelines. It is a stretch from our normal research activities, but will help resource our activities until 2025.

This has been a complex year, with a lot of our research outputs being led by our international collaborators. But I picked out three which span our activity:

[1] The Mark Clilverd-led paper we have been working on togther for some years, validating POES electron precipitation models against AARDDVARK subionospheric VLF data;

[2] Aaron Hendry's GRL which combined space and ground-based observations to investigate

the spatial size of EMIC wave generation (and was an editors highlight);

[3] Craig Rodger's paper looking at how even-order harmonic distortion in power-grid transformers can be used to find "stressed" systems during geomagnetic disturbances - when other measurements are lacking.

The Otago Space Physics Group updated our team picture on 31 July 2020. Shown in the photo from left to right: Craig Rodger, Daniel Mac Manus, Emily Gordon, Keeta Chapman-Smith, Romain Meyrand, Jono Squire, Neil Thomson, Annika Seppälä, Viktoria Nordstrom, Aaron Hendry, Zade Johnston, and Ryan Davis. Unfortunately two groups members were unable to join us: James Brundell and Sam Belcher.

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RUSSIA: Report prepared by Prof. Peter Bespalov (peter@ipfran.ru), Institute of Applied Physics RAS, Nizhny Novgorod, Russia

We obtained new results of a theoretical study on traditional problem connected with the VLF chorus excitation in the magnetosphere. This report is based on the joint work of P.A. Bespalov, O.N. Savina (National Research University Higher School of Economic, Russia), and S.W.H. Cowley (University of Leicester, UK). The work we have done is characterized by the following abstract.

We discuss the physical background of the new mechanism in which short electromagnetic pulses can be strongly amplified by interaction with suprathermal electrons in a near-equilibrium near-uniform magnetised plasma layer. This occurs under the special condition that the wave phase and group speeds along the field lines are equal, a condition met by extraordinary mode electromagnetic waves propagating in the medium. In this case the pulse interacts strongly via the Čerenkov resonance with suprathermal electrons moving along the field lines at the same speed as the pulse, leading to rapid wave growth, the instability within the pulse being shown to be equivalent to that of a monoenergetic electron beam moving along the field lines in an infinite uniform plasma. This effect accounts for basic features of powerful pulsed electromagnetic emissions in planetary magnetospheres, specifically whistler-mode chorus emissions in the magnetosphere.

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RUSSIA: Report prepared by Dr. Andrei Demekhov (andrei@ipfran.ru), Polar Geophysical Institute, Apatity, and Institute of Applied Physics RAS, Nizhny Novgorod, Russia

Our joint group from the two institutes (PGI and IAP RAS) has been continuing our studies of wave-particle interactions in the magnetosphere, in collaboration with our VERSIM Colleagues.

We have analyzed a case where QP VLF emissions were observed on the ground (KAN station in Finland and LOZ station at Kola Peninsula) and by both RBSP spacecraft [Ref. 2 in Jyrki Manninen's report]. We have revealed a plausible position of the source region of these QP emissions by analyzing all available data and calculating the growth rate and ray trajectories of whistler mode waves. This probable source region was crossed by only one spacecraft (RBSP-A), and it was related to a localized density enhancement (duct) with a scale of 700 km across the geomagnetic field. The other spacecraft (RBSP-B) detected the QP emissions outside the probable source region (at a distance by 0.4 in L and 0.7 h in MLT), and with much lower power. These results directly confirm the importance of guided propagation for the generation of QP emissions and demonstrate transverse spreading of VLF waves in radial and azimuthal directions from a localized source flux tube.

Jointly with Czech Colleagues, using Poynting vector measurements of whistler mode chorus emissions detected by the THEMIS spacecraft within the source region, that is, close to the magnetic field minimum, we found both in individual events and statistically that chorus elements propagating equatorward had systematically higher frequencies and smaller amplitudes compared with simultaneously observed elements propagating away from the equator. We demonstrate similar features in the results of numerical simulations based on backward wave oscillator equations. It can be qualitatively explained by the nonlinear evolution of the energetic electron distribution function during wave generation. The motion of electrons from the equator is accompanied by a decrease in their velocity component along the magnetic field line due to both the adiabatic mirror force and nonlinear wave-particle interactions. Thus, the frequency of the chorus elements generated by such electrons and propagating equatorward is higher compared with the elements propagating away from the equator.

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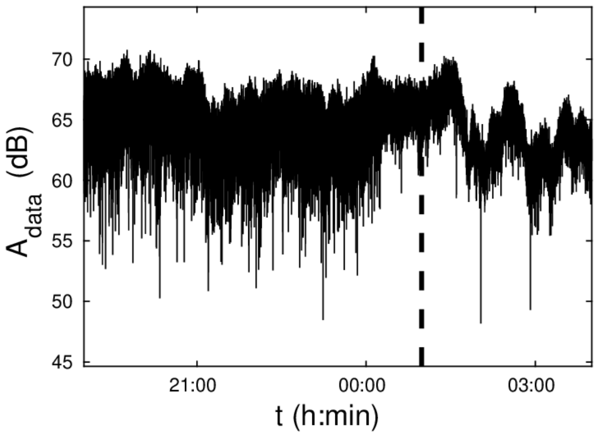
SERBIA: Report prepared by Dr. Aleksandra Nina (sandrast@ipb.ac.rs), Institute of Physics Belgrade, University of Belgrade, Belgrade, Serbia

Researchers from Serbia continued to analyze the data recorded by the VLF/LF receivers located in the Institute of Physics in Belgrade. We carried on with investigations of the D-region perturbations induced by solar X-ray flares and earthquakes, and we continued studies of the perturbed D-region influence on satellite signals. Manuscript related to the ionospheric parameters during quiet condition is submitted. Study of the VLF signal amplitude properties in the period around the Kraljevo earthquake [1] shows the noise amplitude reduction less then one hour before the earthquake. We found thirteen out of a total of 15 (or 87%) decreases of the noise amplitude can be attributed to EQ events. The noise amplitude reduction starting before the EQ event is recorded for all four detected EQs with magnitude larger than 4 in the considered period. Investigation of the solar X-ray flare disturbed D-region on propagation of a satellite signal [2] is continued by research of its influence on SAR meteorology. Jelena Radović and Željko Arsić defended master thesis at the Faculty of Physics, University of Belgrade.

During this year we continue activities in the European VLF/LF network INFREP, EUROPLANET and within COST actions: Accelerating Global science In Tsunami HAzard and Risk analysis, and Atmospheric Electricity Network: coupling with the Earth System, climate and biological system. Aleksandra Nina was elected for president of the Europlanet group in Serbia and for the vice-chair of Europlanet Southeast European Hub.

We participated in several international conferences and organized the Special Issues of Remote Sensing and Atmosphere: „Extraterrestrial Influences on Remote Sensing in the Earth's Atmosphere“ (Eds. Aleksandra Nina, Milan Radovanović and Luka Popović) and „Atmospheric Disturbances: Detecting, Modelling and Influences on Natural Phenomena and Propagation of Telecommunication, GNSS and EO Signal Propagation“ (Eds. Aleksandra Nina, Giovanni Nico and Vladimir Srećković).



Time evolutions of the ICV signal amplitude recorded in Belgrade, Serbia during night-time 2–3 November 2010 when the Kraljevo earthquake occurred. Time resolution of the presented data is 0.1 s, while the vertical dashed line indicates the time of occurrence of the Kraljevo earthquake.

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UNITED KINGDOM: Report prepared by Mark Clilverd (macl@bas.ac.uk), British Antarctic Survey, webpage (https://www.bas.ac.uk/)

BAS report to VERSIM – December 2020

This year I am pleased to be able to say that the Halley Station, Antarctica, VLF experiments have once again operated throughout the whole of 2020 despite the base being unmanned. As in 2019, satellite communications were lost towards the end of the year, resulting in a loss of real-time WWLLN data from Halley, but Ultra, UltraVELOX, and AWD data have continued to be collected. Data uplift will be attempted in January 2021, although BAS's long distance logistics are being severely stretched due to the impact of COVID-19 on international travel.

BROADBAND RECORDINGS in Antarctica:
Whistler-detection and data collection has continued at Halley (L=4.6) and Rothera (L=2.8) throughout 2020 using the Hungarian Automatic Whistler Detection (AWD) system. BAS also continues to operate another AWD site, at Eskdalemuir in Southern Scotland (L=2.7). These sites continue to operate beyond the lifetime of the PLASMON FP7 project which finished in August 2014.

VELOX RECORDINGS at Halley, Antarctica:
Recordings of VLF activity in 10 ELF/VLF bands, at 1-s resolution (VELOXnet) at Halley stopped being collected at the end of 2019 due to IT restrictions on its operating system. However, we have collected broadband data using the VELOXnet upgrade capability, UltraVELOX, at Halley, Rothera, Seattle, and Ottawa. This dataset is partially equivalent to VELOXnet recordings, with 46-93Hz bin resolution up to a maximum frequency of 48 kHz, 0.2-10 sec time resolution depending on site, amplitude only.

NARROW-BAND RECORDINGS:
'Ultra' narrow-band recordings have continued at Halley and Rothera (Antarctica), Forks, Seattle (USA), Ottawa, St Johns, and Churchill (all Canada), Eskdalemuir (Scotland), Sodankyla (Finland), Reykjavik (Iceland), and Ny Alesund (Svalbard) throughout 2020. BAS is also hosting Ultra data from Fairbanks, Alaska, collected as part of a collaboration with WWLLN.

The software VLF Doppler system has continued at Rothera station, Antarctica (L=2.8) in 2020 receiving whistler mode signals primarily from NAA (24.0 kHz). A system upgrade from Windows to Linux was undertaken in February 2020.

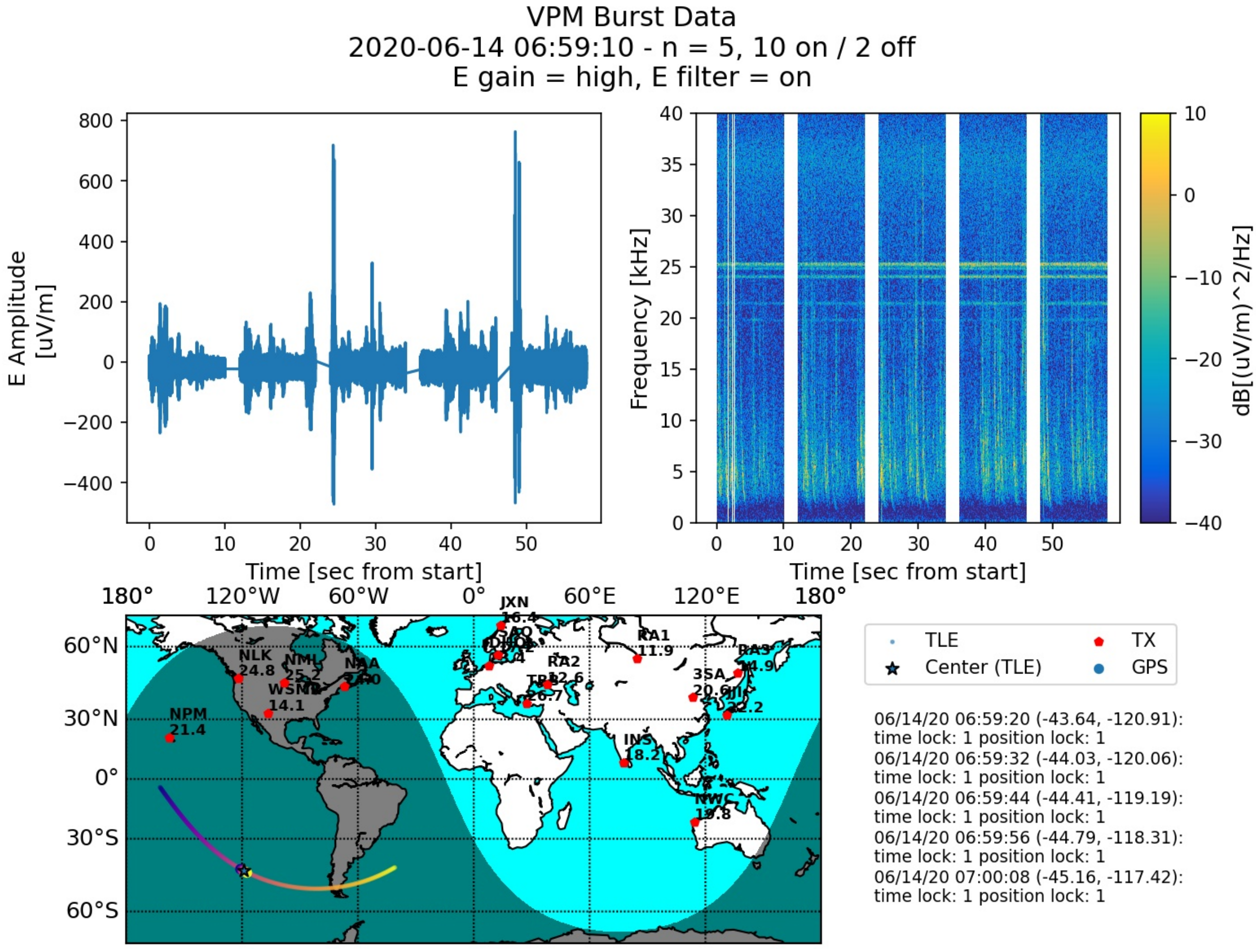
WWLLN sites:
British Antarctic Survey has continued to operate four World Wide Lightning Location Network systems in 2020. St Johns, Ascension, and Rothera have successfully provided lighting location information all year, while Halley has again experienced a 2-3 month datagap during to the loss of network connectivity of the whole site.

Please contact Mark Clilverd (macl at bas.ac.uk) for details regarding on-line access to the datasets mentioned above.

Regards, Mark Clilverd

UNITED STATES: Report prepared by Prof. Robert Marshall (robert.marshall@colorado.edu), University of Colorado Boulder, Boulder, CO, USA

The Lightning, Atmosphere, Ionosphere, and Radiation belts research group (the LAIR) continues to make VLF/LF observations, conduct modeling studies, and build instrumentation. Among our recent work, we have started in-depth analysis of the VLF/LF radio data collected by four receivers in Argentina as part of the Nov-Dec 2018 RELAMPAGO campaign to study high-flash rate thunderstorms. PhD candidate Andre Antunes de Sa has analyzed all of this data, developed his own lightning geolocation algorithms, and created a classification algorithm to identify and study energetic in-cloud lightning. His scientific results will be completed in early 2021 as he graduates with his PhD.



An example of burst data from the VPM mission. Top plots show calibrated time series data (left) and spectrogram (right) from the E-field antenna; the data shows nice examples of whistlers as well as numerous VLF transmitters. The bottom panel shows the map, with VPM in the south pacific ocean, roughly conjugate to the USA, indicating that these transmitter signals are conjugate observations.

This year saw the successful launch and deployment of the Very-low-frequency Propagation Mapper (VPM) CubeSat, led by AFRL, but whose VLF receiver was built by our team. Over the past year, our group has been involved in mission planning, data processing, and now scientific data analysis. The VPM spacecraft operated successfully for about six months (from late February to early September 2020), before losing communications with the ground station. Despite the early failure, VPM collected excellent electric field wave data (0-40 kHz), including magnetic conjunctions with the DSX spacecraft. Ongoing data analysis is being led by PhD student Riley Reid and research scientist Maria Usanova.

The development of the Climatology of Anthropogenic and Natural VLF wave Activity in Space (CANVAS) CubeSat has continued, largely led by a team of students. This 4U CubeSat will use a three-axis search coil and two dipole antennas to measure VLF waves from Low Earth Orbit (see Figure). The search coils were provided by a group at CNRS led by Thierry Dudok de Wit. We have completed the design and manufacturing of our electric field antennas and preamplifiers, and are now finishing up the analog and digital instrument electronics and firmware. At the same time, the student team is developing all of the spacecraft bus components, including the structure, solar panels, electronics, and communications systems. The COVID pandemic has slowed development somewhat, but we are expecting to be ready to launch in mid-2022.

Our group is also continuing the development of the Atmospheric Effects of Precipitation through Energetic X-rays (AEPEX) CubeSat mission, which will measure the flux, spectrum, and spatial scale of precipitation from the radiation belts by measuring the X-rays backscattered from the atmosphere. The AEPEX mission has completed its Preliminary Design Review and is approaching Critical Design Review in January 2021. A large part of the ongoing development is the design, fabrication, and testing of a novel hard X-ray imaging spectrometer, led by PhD student Grant Berland. AEPEX will also likely launch in mid 2022. While it will not make direct measurements of waves in the magnetosphere, possible conjunctions with other spacecraft (including CANVAS) will enable new insights into the causes and consequences of radiation belt precipitation.

UNITED STATES: Report prepared by Prof. Jacob Bortnik (jbortnik@gmail.com), University of California at Los Angeles (UCLA), Los Angeles, California, United States.

The Bortnik Research Group at UCLA had a fun and productive year, looking at some of the key physical processes occurring in the Earth's inner magnetospheric environment through a combination of multi-spacecraft data analysis, numerical simulation, and techniques in machine learning.

A few big themes emerged in our research in 2020: the characteristics and dynamics of ultrarelativistic electrons in the Earth's radiation belts (known as remnant belts), in particular the relationship between the much-studied electron fluxes at Geosynchronous Earth Orbit compared to energetic electron fluxes at lower L-shell regions [Pinto et al., 2020], the timescale of radiation belt decay due to various loss mechanisms [e.g., Claudepierre et al., 2020, figure below], wave-particle interactions between energetic electrons and various plasma waves such as VLF transmitters, chorus, and lightning-generated whistler waves [e.g., Martinez-Calderon et al., 2020], as well as a host of related topics such as ULF wave dynamics, energetic ion field-aligned beams, Pi2 pulsations associated with fast flows in the plasmasheet, foreshock transients, and even potential precursors to large Earthquakes. We also enjoyed being involved in the organization of the hugely successful VERSIM workshop which took place online, but based in Kyoto, Japan in November 2020.

As good as this year has been, we also recognize the unprecedented challenges and hardships imposed by the COVID-19 pandemic on our group members, friends, and colleagues all over the world. We hope that the new year brings with it healing and restoration, and look forward to seeing our colleagues again (in person) soon.

References:

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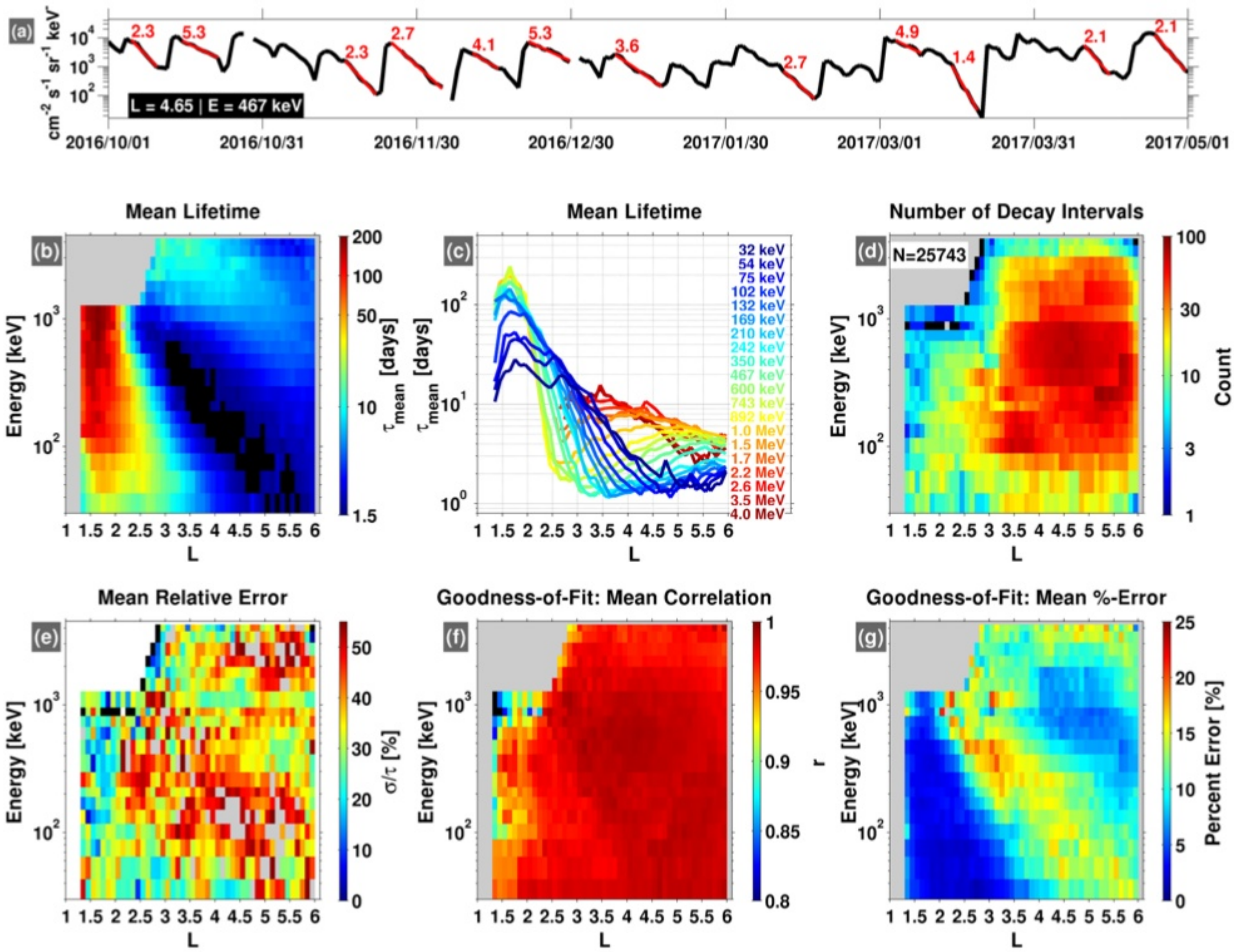
VERSIM JOURNAL CLUB (INTERNATIONAL): Report prepared by Dr. Claudia Martinez-Calderon (claudia@isee.nagoya-u.ac.jp), ISEE, Nagoya U., Japan; Miroslav Hanselka (mha@ufa.cas.cz), IAP, Czechia; Lilla Juhász (lilla@sas.elte.hu), Eötvös U., Hungary; Dr. Liliana Macotela (macotela@iap-kborn.de), IAP, Germany.

During the 8th VERSIM workshop, held in Apatity, Russia, Claudia Martinez and Liliana Macotela came up with the idea of creating a journal club. The main objective of this group was to discuss published papers of interest to the VERSIM community among early career scientists, and hopefully with the guide of senior scientists. In particular, we wanted to encourage scientific discussion between students and scientists in a more casual and low-stress environment.

Since then, we have held 24 journal club sessions, including 5 special sessions with invited senior scientists. The sessions started in April 2018, and are usually held monthly with summer and winter breaks. Depending on the topics of interest to our members, we choose a speaker and a paper to read and discuss over Zoom. This gives us the opportunity to interact among early career scientists to get a better understanding of the science, but also keep in touch between VERSIM workshops.

We have discussed a large range of topics, including but not limited to: properties of VLF waves (QP emissions, chorus, auroral hiss), non-linear wave generation, lightning and its



(After Claudepierre et al., 2020, Fig 1.) A summary of the observationally deduced decay timescales of energetic electrons showing the (a) energetic electron flux at L=4.65 and E=467 keV; (b) and (c) mean lifetime versus energy and L-shell; (d) the number of decay intervals considered, and (e)-(g) error metrics.

influence on particle precipitation, D-region changes, particle dynamics in the radiation belts, etc.

An exhaustive list of our previous paper discussions can be found here: http://www.iugg.org/IAGA/iaga_ursi/versim/journal_club.html

We have also created a WhatsApp Group so that we can keep in touch more easily, and to create a space where students can ask more experienced scientists questions about scientific and professional matters.

After two years co-chairing the journal club, Liliana stepped down from her duties in November 2020. Her role will be taken over by Miroslav Hanzelka (Ph.D student, IAP Czechia) and Lilla Juhász (Ph.D student, Eötvös U.). Claudia will continue her involvement with the Journal Club to a lesser degree, helping the new leaders.

More information: versim.jc@gmail.com