V Meeting on Astrophysical Spectroscopy -

A&M DATA - Astronomy & Earth Observations

September 12 - 15, 2023, Palić, Serbia

BOOK OF ABSTRACTS AND CONTRIBUTED PAPERS

Edited by Vladimir A. Srećković, Milan S. Dimitrijević, Aleksandra Kolarski, Zoran R. Mijić and Nikola B. Veselinović

A&M DATA

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NATIONAL INSTITUTE OF THE REPUBLIC OF SERBIA

Belgrade 2023

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ISBN 978-86-82441-61-8

Financially supported by the Ministry of Science, Technological Developement and Innovation of Serbia

Production: Skripta Internacional, Mike Alasa 54, Beograd in 50 copies

SCIENTIFIC RATIONALE

Efficiency of theoretical analysis, synthesis and modeling of various environments, depends on atomic data and their sources. In particular, for the modeling of stellar atmospheres and opacity calculations a large number of atomic data is needed, since we do not know a priori the chemical composition of a stellar atmosphere. The same holds for Earth observations. Consequently, the development of databases with atomic data as well as astro-geoinformatics is important. This meeting will bring together physicists, astro & geophysicists from Serbia and elsewhere to review the present stage of research in this field. The meeting is planned as an opportunity to consider the above-mentioned aspects of spectroscopic research on plenary sessions and then to work on the special mini-projects, which will result in common papers to be published in international scientific journals.

Venue

Palić, (Hotel Prezident – Palić), Serbia

CONTENTS

Invited Lectures

On the Stark broadening parameters of N VI spectral lines

Magdalena D. Christova[1], Milan S. Dimitrijević[2,3] and Sylvie Sahal-Bréchot[3]

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Stark broadening data, or data for broadening by collisions with charged particles, are of interest in many research topics. They are particularly needed for astrophysical plasma research, but also for laboratory plasma diagnostics, for fusion plasma, laser research and for various plasmas in technology.

Data for Stark broadening of five times charged nitrogen ion (N VI) spectral lines are important particularly for investigation of white dwarfs where N VI lines are present (see e.g. Rauch 2007) and Stark broadening is the dominant pressure broadening mechanism. Reliable data for Stark broadening of N VI are also of interest for proton-boron fusion plasma since in a number of investigations (see e,g, Margarone et al. 2014, Giuffrida et al. 2020, Istokskaia et al. 2023) the target is boron nitride (BN).

Using the semiclassical perturbation theory (see Sahal-Bréchot, Dimitrijević and Ben Nessib, 2014 and references therein), we calculated Stark widths and shifts, determining line profile, for 15 multiplets containing 33 spectral lines of N VI broadened by collisions with the most important charged constituents of stellar and proton-boron fusion plasma: electrons, protons, alpha particles, B III, B IV, B V and B VI ions. Calculations have been performed for a grid of temperatures and perturber densities. The obtained results will be also prepared in VO (Virtual Observatory) and XSAMS (XML Schema for Atomic, Molecular and Solid Data) format for the implementation of results in the international, on-line database STARK-B (Sahal-Bréchot et al. 2015 - https://stark-b.obspm.fr/) a part of VAMDC (Virtual Atomic and Molecular Data Center, Dubernet et al., 2010 - https://portal.vamdc.org/vamdc_portal/home.seam), after the publication of the main article.

In this contribution we will present and discuss a part of results which will be published in entirety elsewhere (Dimitrijević, Christova and Sahal-Bréchot 2023).

References

Dimitrijević, M. S., Christova, M. D., Sahal-Bréchot, S., 2023, to be submitted.

Dubernet, M., Boudon, L. V., Culhane, J. L., Dimitrijević, M. S., et al., 2010, J. Quant.Spectrosc. Radiat. Transfer, 111, 2151.

Giuffrida, L., Belloni, F., Margarone, D., et al., 2020, *Physical Review E,* 101, 013204.

Istokskaia, V., et al., 2023, Communications Physics**,** 6, 27.

Margarone, D., et al., 2014, *Plasma Physics and Controlled Fusion,* 57, 014030.

Rauch, T., 2007, A&A, 470, 317.

Sahal-Bréchot, S., Dimitrijević, M. S., Ben Nessib, N., 2014, Atoms 2, 225.

Sahal-Bréchot, S., Dimitrijevć, M. S., Moreau, N., Ben Nessib, N., 2015, Phys. Scr., 50, 054008

Dissociative Recombination and ro-vibrational excitation of molecular cations by electrons: new datasets (cross sections and rate coefficients) - impact in astrophysics

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The Multichannel Quantum Defect Theory (MQDT) has used in computing cross sections and Maxwell rate coefficients for electron-driven reactions involving molecular cations. These data are usefully in the modelling of the kinetics of various cold ionized media of fundamental and applied interest. Rotational and vibrational transitions (RVT) and dissociative recombination (DR) rate coefficients, an extension of our previous studies (Motapon et al., 2014, Epée et al., 2016, Djuissi et al., 2020) and outline several important features, as isotopic and resonant effects are presented. The provided collisional data are usefully in the kinetics modeling in astrochemistry - early Universe, interstellar molecular space and cold plasma physics.

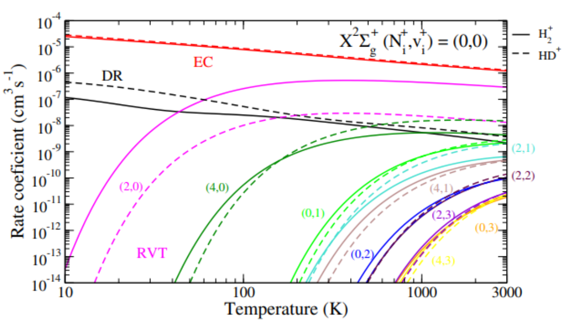

Fig. 1. Electron-impact DR and ro-vibrational transitions of HD^+ and H_2^+.

References

Djuissi, E., Pop, N., et al., 2020, *Rom. Astron. J.* **30**, 101

Epée, M. D., Mezei, J. Zs, Motapon,O., Pop, N., Schneider, I. F., 2016, *MNRAS* **455**, 27

Motapon, O., Pop, N., Argoubi, F., Mezei, J. Zs, Epee Epee, M. D., Faure, A., Telmini, M., Tennyson, J., and Schneider, I. F., 2014, *Phys. Rev. A* **90**, 012706

Simulations of positive and negative streamers in the AMReX environment

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Streamers are thin channels of weakly-ionized nonstationary plasma produced by an ionization front that moves through non-ionized matter (Teunissen and Ebert 2017). They have applications in diverse areas of science and technology ranging from their role in creating lighting and sprite discharges in the upper planetary atmospheres to industrial applications such as the ignition of high-intensity discharge lamps and treatment of polluted gases and water. Further optimization and understanding of such applications are dependent on an accurate knowledge of streamer properties, electron transport and physical processes involved.

We have developed a computer code that implements an axisymmetric first order fluid model in the AMReX environment. AMReX is an open-source C++ library for numerical calculations with block structured adaptive mesh refinement (Zhang et al. 2019). It has inbuild geometric multigrid solvers and it allows both MPI and OpenMP parallelization, as well as parallelization on graphic processing units. AMReX also has many inbuilt classes which enable a convenient implementation of both grid and particle data.

In our code the time evolution of the number density of electrons is represented by the drift-diffusion-reaction equation. The time evolution of the number densities of positive and negative ions are represented by the rate equations, as ions are assumed to be stationary for the timescales of our simulations. The time integration of these equations is performed by employing the second order Runge-Kutta method. The spatial dependence of transport coefficients in these equations is represented by the local field approximation. The electric potential due to space charges is determined by solving the Poisson equation, while photoionization is represented by solving a set of Helmholtz equations. These equations are solved by employing the AMReX inbuilt geometric multigrid solver. Bourdon three term parametrization (Bourdon et al. 2007) is employed for representing photoionization in the mixtures of nitrogen and oxygen.

Spatial discretization is implemented by using the finite volume method. Thus, scalar variables are defined at the cell centers, while vector variables are defined at the cell faces. For this reason, the number density of electrons needs to be interpolated from cell centers to cell faces to calculate the electron flux. For this purpose, both TVD scheme with the Koren flux limiter (Koren 1993) and Munz implementation (Munz 1988) of the MUSCL scheme (Van Leer 1979) can be used. The validity of the code is tested by comparing its results to the results of the Afivo-streamer open-source fluid code (Teunissen 2017).

Acknowledgments

This work is supported by the Science Fund of the Republic of Serbia, Grant No. 7749560, Exploring ultra-low global warming potential gases for insulation in high-voltage technology: Experiments and modelling EGWIn.

References

Bourdon, A., Pasko, V. P., Liu, N. Y., Célestin, S., Ségur, P. and Marode, E., 2007, Plasma Sources Sci. Technol. 16, 656

Koren, B., 1993, In Numerical Methods for Advection-Diffusion Problems, pages 117–138. Braunschweig/Wiesbaden: Vieweg

Munz, C. D., 1988, J. Comput. Phys., 77, 18

Teunissen, J. and Ebert, U., 2017, Journal of Physics D: Applied Physics 50, 474001

Van Leer, B, 1979, Journal of computational Physics, 32, 101

Zhang, W. et al., 2019, Journal of Open Source Software, 4, 1370

Study of radio spectral index of radio galaxy DA 240

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Here we investigate the giant radio galaxy DA 240, which is a FRII source. It is an example of Double Radio source Associated with Galactic Nucleus (DRAGN) (see Leahy 1993). DA 240 was among the first giant radio galaxies to be recognized as such, and a study of its environment can be found in Peng et al. 2004. It consists of two radio clouds about 40' long, and a comparatively weak central core (Artyukh & Ogannisyan 1988).

Specifically, we investigate its flux density, as well as the spectral index distribution. For that purpose, we used publicly available data for the source: Leahy's atlas of double radio-sources (Laing, Riley & Longair 1983 and Leahy, Bridle & Strom 2013) and NASA/IPAC Extragalactic Database (NED) (Mazzarella and the NED Team 2002). We use observations at 326 MHz (92 cm) and at 608 MHz (49.3 cm).

We obtained spectral index distributions between 326 and 608 MHz. For the first time we give spectral index map for these frequencies. We found that the synchrotron radiation is the dominant radiation mechanism over most of the area of DA 240, and also investigated the mechanism of radiation at some characteristic points, namely its core and the hotspots. The results of this study will be helpful for understanding the evolutionary process of the DA 240 radio source.

References

Artyukh, V. S., Ogannisyan, M. A., 1988, Sov. Astron. Lett. 14, 301

Laing, R. A., Riley, J. M., Longair, M. S., 1983, Mon. Not. R. Astron. Soc. 204, 151

Leahy, J. P., "DRAGNs", 1993, in Proceedings: Jets in Extragalactic Radio Sources, Eds. H.-J. Roser and K. Meisenheimer, Lecture Notes in Physics 421, 1

Leahy, J. P., Bridle, A. H., Strom, R. G., 2013, An Atlas of DRAGNs - online: http://www.jb.man.ac.uk/atlas/

Mazzarella, J. M., and the NED Team, "Using the NASA/IPAC Extragalactic Database (NED) and Federated Virtual Observatory Archives for Multiwavelength Studies of AGN", in Proceedings: AGN Surveys, Eds. R. F. Green, E. Ye. Khachikian and D. B. Sanders, 2002, Astron. Soc. Pacific Conference Series 284, 379

Peng, B., Strom, R. G., Wei, J., Zhao, Y. H., 2004, Astron. Astrophys., 415, 487

Constraining theories of gravity by velocity distribution of elliptical galaxies

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The velocity distribution of elliptical galaxies can be used in the framework of f(R) gravity to constrain these theories avoiding the issues related to dark matter to fit the observations. In particular, we used the power-law version f (R) $\propto$ R^n (Borka Jovanović et al., 2016; Borka Jovanović et al., 2019), Yukawa-like gravity model (Capozziello et al., 2020), Sanders (Capozziello et al., 2014), Hybrid (Borka Jovanović et al., 2021) and non-local (Borka et al., 2023) gravity model in the weak field limit.

We compared theoretical predictions for circular velocity in above mentioned gravity models with the corresponding values from a large sample of observed elliptical galaxies. In our investigations, from this sample of data, we use surface brightnesses, effective radius and velocity dispersion. In this way, we are able to constrain the different gravity parameters. We showed that the gravity parameters are scale-length depending on the gravitational system properties. Also, we showed that analysed modified gravity models are able to reproduce the stellar dynamics in elliptical galaxies. These gravity models fit the observations very well, without the need for a dark matter.

References

Borka, D., Borka Jovanović, V., Capozziello, S., Jovanović, P., 2023, Advances in Space Research 71, 1235

Borka Jovanović, V., Borka, D., Jovanović, P., Capozziello, S., 2021, Eur. Phys. D 75, 149

Borka Jovanović, V., Capozziello, S., Jovanović, P., Borka, D., 2016, Physics of the Dark Universe 14, 73

Borka Jovanović, V., Jovanović, P., Borka, D., Capozziello, S., 2019, Atoms 7(1) 4
Capozziello, S., Borka, D., Jovanović, P., Borka Jovanović, V., 2014, Phys. Rev. D., 90, 044052
Capozziello, S., Borka Jovanović, V., Borka, D., Jovanović, P., 2020, Physics of the Dark Universe 29, 100573

On the Stark broadening parameters of Al IV spectral lines for stellar spectra analysis and synthesis

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For different astrophysical research topics, as e.g. modelling of stellar atmospheres and subphotospheric layers or analysis and synthesis of spectral lines, data on Stark broadening of spectral lines, namely broadening of spectral lines by interactions with electric microfield of surrounding charged particles, are usful. Such data enter in the calculations of absorption coefficient, opacity, radiative transfer, abundance determination, acceleration of gravity etc. They are also of importance for laboratory plasma diagnostic and modelling, inertial fusion plasma investigation, laser design and development, laser produced plasma research and plasmas in different technologies and industries.

The importance of aluminum in stellar plasma and spectra research is due to its high cosmic abundance since it is the twelfth most common element in the Universe, and spectral lines of this element and its ions are commonly present in stellar spectra. Since for astronomy are particularly important lines in the visible part of the spectrum, we calculated Stark widths for 23 Al IV transitions in this part of the spectrum, employing the modified semiempirical method (Dimitrijević and Konjević 1980). Calculations have been performed for an electron density of 10^{17} cm^{-3} and electron temperatures of 10,000, 20,000, 40,000, 80,000 and 160,000 K.

We used the obtained results to examine the influence of Stark broadening on Al IV spectral lines in A-type stellar atmospheres, as well as in DB and DO white dwarfs. In comparison with lines in UV (Dimitrijević and Christova 2022), the influence of Stark broadening in the visible part of the spectrum is higher due to the influence of higher wavelengths. Namely, in the modified semiempirical method and other Stark broadening theories, the wavelength enters as a square and the formula for Doppler width has linear behavior with wavelength. Therefore, for the higher wavelengths of spectral lines Stark width values will be larger in comparison with Doppler ones. Consequently, in the visible part of the spectrum, the corresponding Stark width will be higher in comparison with Doppler width, than in the UV part.

Additionally, since all examined transitiona are in Jl coupling, we examined similarities of Stark widths within multiplets and supermultiplets for this type of coupling. We found that for the analyzed Al IV transition in the Jl coupling, these differences may be of the order of 10–20 percent if expressed in angular frequency units, which enables a rough check of consistency of existing experimental and theoretical data or an approximate check during experiment or calculation. In the case of considered Al IV supermultiplets in Jl coupling, differences are between 210% and 61%, so that there is no similarities which could be used for checking the consistency of Stark width values or to estimate the missing Stark width in a supermultiplet from the known ones, like in the case of LS coupling.

Since such results are also of interest for Virtual Observatories we will prepare them additionally for implementation in STARK-B database (Sahal-Brechot, et al. 2015), which is also a part of Virtual Atomic and Molecular Data Center - VAMDC (Dubernet et al. 2010).

Obtained results are published in the Special Issue: ""New Insights into Astronomy and Earth Observations: From Observations to the Theory" of "Universe" for some results of this Conference.

References

Dimitrijević, M. S., Christova, M. D., 2022, Universe, 8, 430

Dimitrijević, M. S., Christova, M. D., 2023, Universe, 9, 126

Dimitrijević, M. S., Konjević, N., 1980, J. Quant. Spectrosc. Radiat. Transf, 24, 451

Dubernet, M. L., Antony, B. K., Ba, Y. A., Babikov, Y. L., Bartschat, K., Boudon, V., Braams, B. J., Chung, H. K., Daniel, F., Delahaye, F., et al., 2016, J. Phys. B, 49, 074003

Sahal-Bréchot, S., Dimitrijević, M. S., Moreau, N., STARK-B Database. Available online: http://stark-B.obspm.fr (accessed on 2 March 2023).

Experimental and theoretical differential cross sections for elastic electron scattering from isoflurane molecule at 100eV

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Abstract

We present joint theoretical and experimental absolute differential cross section for elastic electron scattering from isoflurane molecule, for incident electron energy of 100 eV. Motivation for this research has been found in influence on global warming and ozone destruction.

Introduction

Isoflurane(2-chloro-2-(difluoromethoxy)-1,1,1-trifluoroethane,CF_3CHCl-O-CHF_2) It is a non-flammable halogenated ether, with a molecular weight of 184.49 g/mol, a boiling point of 48.5°C, a vapor pressure of 330 mmHg (Pub Chem), and an estimated dipole moment of 2.47D (Atomistic Models of General Anesthetics for Use in in Silico Biological Studies). Mostly because of its clinical usage, isoflurane is widely investigated, but lately, its impact on the environment has motivated further research. Namely, it is known that most of the inhaled aneaesthetics are eliminated from the patient's body without being metabolized, so they are released into the lower atmosphere (Shiraishi et al. 1990). Atmospheric lifetime of isofurane is calculated to be between 2 and 5.9 years (Langbein et al. 1999), long enough to reach the stratosphere in considerable quantities. Isoflurane is known to have a high global warming potential (GWP) and it is calculated to be 545 according to (Langbein et al. 1999) and there, isoflurane can damage the ozone layer. All the above-mentioned give enough motive for research of electron interaction with this molecule.

Absolute differential cross sections of elastic electron scattering from isoflurane molecule, for incident electron energy 100 eV are reported. The experiment is performed in crossed beam setting. Relative differential cross section (DCS) is normalized on the absolute scale using the relative flow method, with Ar as a reference gas. The theory is obtained with IAM+SCAR method (Independent Atom Model + Screening Corrected Additivity Rule). A schematic drawing of halothane is shown in Fig. 1.

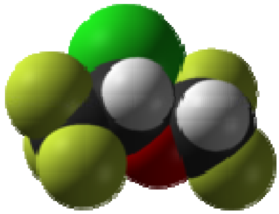

Fig. 1. Schematic drawing of isoflurane.

Experimental set up

Crossed electron-molecular beam apparatus UGRA which has been described in detail previously by Milosavljevic et al. (2006), was used for measuring absolute differential cross sections for elastic electron scattering on a halothane. The experimental set-up consists of an electron gun (hairpin electron source, up to about 1 μA incident beam current in the energy range from 40-300 eV, a double cylindrical mirror energy analyzer (DCMA) and a channel electron multiplier as a detector. All of these components are enclosed in a double μ–metal shielded vacuum chamber. The incident electron beam is crossed perpendicularly by a molecular beam produced by stainless still needle. The electron gun can be rotated around the needle in the in a limited angular range, from -40° to 125°.The base pressure of about $4x10^{-7}$ mbar was obtained by a turbo-molecular pump. The working pressure was usually less than $5x10^{-6}$ mbar and was checked for each experimental point. The energy resolution is limited by a thermal spread of primary electrons to about 0.5 eV. Isoflurane was introduced into scattering region from a glass container via a gas line system which was heated (sample container, pipes, needle) to provide stable experimental conditions and to improve the signal. Temperature of the pipes, needle and container were kept at about 40^{o}-50^{o}C. Absolute values for differential cross sections (DCSs) were obtained for 100eV incident electron energy, using relative flow technique (Nickel et al. 1989), at several scattering angles (40 and 70, 80 or 90 degrees.). In the relative flow method, the DCS for scattering of the unknown gas is determined by comparing scattering signals from a standard target (Ar), with its known differential cross sections (Ranković et al 2018), at a given incident electron energy (E_O) and a scattering angle (θ) under identical experimental conditions. To obtain the same profiles for both gas beams, the gases must be operated at pressures behind the needle so that their mean-free paths are the same.

Gas kinetic diameter for argon ($D_{ref}=D_{Ar}$) is known to be 3.58 Å and the estimated value for isoflurane ($D_x=D_{IF}$) is 5.57 Å. For the present experiment, the ratio of driving pressures (according to their gas-kinetic diameters) is p_{Hal}: p_{Ar}=2.4:1. During the measurement it has been proved by varying the ratio of the halothane and Ar pressures (±20%) that absolute values of the cross sections do not depend significantly.

Analysis and results

Experimentally measured (green circles, for scattering angles from 20° to 110°) and theoretically calculated (black full line, 0°-180°) DCSs, for incident electron energy 150 eV, are shown graphically in Fig. 2. DCS has characteristic behavior for molecular targets, as noticed before (Vukalović et al. 2021). It exhibits a wide minimum at about 90°. Experiment and theory are, in general, in very good agreement, considering absolute scale and shape. Concerning the normalization procedure, described in detail elsewhere (Vukalović et al. 2021), relative flow measurements are shown in Fig. 2. as yellow stars. The reference gas used was Ar, and its absolute DCS values were taken from a paper by Ranković et al.

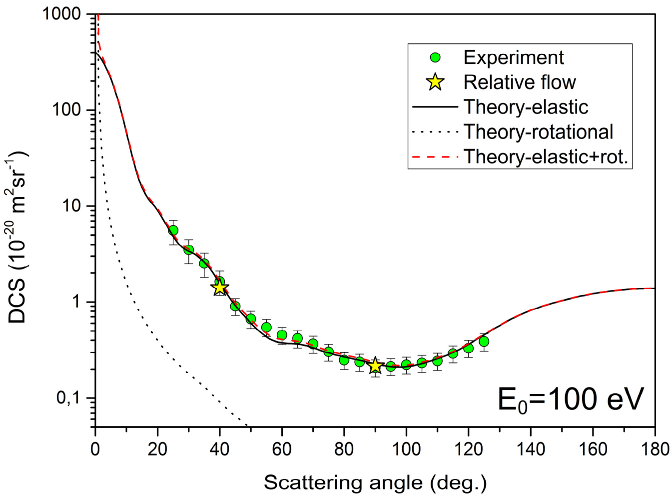

Fig. 2. Angulary dependent differential cross section for elastic electron scattering from isoflurane molecule, for incident electron energy 100 eV.

Acknowledgments

We acknowledge the financial support of MESTD supplied via Institute of Physics Belgrade. This collaborative work has been undertaken under COST Actions: CA18212 MD-GAS and CA 20129 MultIChem.

References

Atomistic Models of General Anesthetics for Use in in Silico Biological Studies https://doi.org/10.1021/jp502716m.

Langbein, T., Sonntag, H., Trapp, D., Hoffmann, A., et al., 1999, Br. J. Anaesth., **82,** 66

Milosavljević, A. R., Mandžukov, S., Šević, D., Čadež, I., Marinković, B. P.: 2006, J. Phys. B: At. Mol. Opt. Phys., **39,** 609

Nickel, J. C., Zetner, P. V., Shen, G. and Trajmar, S.: 1989, J. Phys. E: Sci. Instrum., **22,**730

PubChem, https://pubchem.ncbi.nlm.nih.gov/

Ranković, M., Maljković, J. B., Tökési, K., Marinković, B. P., 2018, Eur. Phys. J. D, **72**, 30

Shiraishi, Y., Ikeda, K., 1990, J. Clin. Anesth., 2, 381

Vukalović, J., Maljković, J. B., Blanco, F., García, G., et al., 2021, Int. J. Mol. Sci. **23**, 10021

Vukalović, J., Maljković, J. B., Tökési, K., Predojević, B., Marinković, B. P., 2021, Int. J. Mol. Sci. **22**, 647

The role of breakdown data in atmospheric studies

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Non-equilibrium low-temperature plasmas are a common phenomenon both on Earth and in space. There are remarkable similarities in many fundamental properties between low-temperature plasmas in various fields, including gas discharges, space science, the near-Earth environment, atmospheric discharges/electricity, and semiconductor physics. An example of this is the creation of different groups of electrons (with varying energies), which is a common occurrence in DC, RF, capacitive, and inductive discharges, as well as space plasma (solar wind) (Kolobov et al. 2020, Kolobov and Godyak 2019). The study of runaway electrons, in particular, can help us understand the initiation of lightning and thunderstorm activity in the troposphere, as well as the formation of electric discharges such as elves, sprites, and jets in the stratosphere and mesosphere. This is especially interesting because runaway electrons tend to occur in front of fast ionization waves, streamers, and leader tips during natural lightning. However, progress in studying and understanding atmospheric discharges on Earth and other planets demands a multidisciplinary approach and collaboration between researchers from different fields.

Studying the breakdown and electrical characteristics of discharges can provide insights into the fundamental properties and processes at play, and help identify new phenomena through experimental observations. By conducting our experimental measurements of breakdown conditions, we are able to gain valuable knowledge of the elementary processes that occur during discharges, including ionization, secondary electron emission, and surface interactions. We will discuss the results of our experimental measurements of breakdown in water vapor and low ODP (Ozone Depletion Potential) and low GWP (Global Warming Potential) gases, specifically 1,1,1,2-tetrafluoroethane (R-134a) and 2,3,3,3-tetrafluoropropene (HFO-1234yf). These measurements yielded breakdown voltages (Paschen curves), critical electrical fields, spatially and spectrally resolved distribution of discharge emission, and effective ionization coefficients. Using the available cross-section data, we analysed the collisional processes in these gasses. Furthermore, obtained effective ionization coefficients (in the region of reduced electric field *E/N* from 680 Td to 6.5 kTd for water vapor, from 2.7 kTd to 6 kTd for R-134a, and from 5 kTd to 23 kTd for HFO-1234yf), as one of the key transport coefficients, can be utilized to normalize existing ionization cross-sections for electron scattering on gases (Petrović et al. 2022, Marić et al. 2014). The implications of these results extend to both atmospheric research and practical applications.

Acknowledgements

This research was supported by the Science Fund of the Republic of Serbia, Grant No. 7749560, project EGWIn. Zoran Lj. Petrović is grateful to the SASA project F155.

References

Kolobov, V., et al, 2020, J. Phys.: Conf. Ser., 1623, 012006
Kolobov, V., and Godyak, V., 2019, Phys. Plasmas, 26, 060601
Marić, D., Savić, M., Sivoš, J., Škoro, N., Radmilović-Radjenović, M., Malović, G., Petrović, Z., Lj., 2014, Eur. Phys. J. D, 68, 155
Petrović, Z., Lj., et al., 2022, Eur. Phys. J. D, 76, 25

Study on 2021 November 4 Forbush decrease with Belgrade muon station

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The first significant Forbush decrease of rising phase of the solar cycle 25 was recorded on November 4, 2021. It was detected with numerous ground based cosmic rays stations around the world (Chilingarian et al. 2022). including Belgrade cosmic rays muons' station. Belgrade cosmic rays' muon station is located at the Institute of Physics Belgrade and it constantly measures muon flux during cycle 24 (and 25) originated from primary cosmic rays with higher median energy then neutron monitors (Veselinović et al. 2017). This rapid decrease in the observed galactic cosmic ray intensity was the result of a series of coronal mass ejections during October 28–November 2. (Li et al. 2022), and their interplanetary counterparts (ICME) that led to strong G3-class geomagnetic storm, auroras and even first Ground Level Enhancement of the cycle 25 (Papaioannou et al. 2022). We discuss here the variation of cosmic rays' flux detected with ground-based detectors with different median rigidity during this recent event. Also, we compare conditions, measured in-situ, in interplanetary space around Earth, flux of solar wind protons measured with SOHO/ERNE probe, at Lagrange Point 1 and properties of detected Forbush decrease in order to asses implication for solar-terrestrial coupling processes.

References

Chilingarian, A., Hovsepyan, G., Martoyan, H., Karapetyan, T., et al., 2022 https://arxiv.org/abs/2212.13514

Li, X., Wang, Y., Guo, J., Lyu, S., 2022 *ApJL* 928 L6

Papaioannou, A., Kouloumvakos, A., Mishev, A., Vainio R., et al.,2022, A&A, 660 L5

Veselinović, N., Dragić, A., Savić, M., Maletić, D., et al. 2017, NiM A, 875

Galactic Cosmic Ray Variation Caused by Different Structural Elements of Isolated Earth-Impacting Coronal Mass Ejection

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In this work we investigate the characteristics of galactic cosmic rays (GCR), within different structural elements of isolated Earth-impacting interplanetary coronal mass ejections (ICMEs). Observations from different satellite viewpoints are used to determine if the CME in our study is Earth directed or not. For Earth-directed CMEs, a kinematical study was performed for estimation of the CME arrival time at 1 AU and to link the CME with the corresponding in situ solar wind signatures, as well as variation in cosmic rays (CR) flux. Based on the extrapolated CME kinematics, we identified interacting CMEs and flank encounter CMEs, which were excluded from further analysis. Using this approach, a set of 17 isolated Earth-impacting CMEs were unambiguously identified and related to the corresponding in situ solar wind and CR flux variations. We divided the isolated Earth-impacting ICME structure on three different structural elements defined as: the turbulent sheath (TS), the frontal region (FR), and the magnetic obstacle (MO) itself. Hence, we analyzed in more detail the variation of magnetic field strength, the plasma characteristics and CR flux within these three different segments of ICME. The analysis revealed well-defined correlations between variations of the CR caused by TS and the rest of the ICME segment (joined FR and MO), with very high correlations of cc ~ 0.8. A mathematical model, capable of describing the distribution of the cosmic-ray density in different segments of ICME is considered.

Keywords: Galactic cosmic ray, Coronal mass ejection, Magnetic obstacle, Neutron monitors

Lower ionosphere influenced by high-class Solar flare events as observed through VLF measurements

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Abstract

Solar flare events, the powerful explosions on Sun, are one of the most significant drivers of the lower ionospheric behavior related to solar activity. During occurrence of solar flare events, emanated electromagnetic energy within X-ray radiation of soft range (0.1-0.8 nm) impacts Earth within only several minutes, passing though the Earth's atmosphere and reaching D-region altitudes (50-90 km), causing ionization of its constituents on the sunlit side of the Earth. Additional ionization ultimately leads to perturbations of the Very Low Frequency (VLF) radio signals (3-30 kHz) propagating within Earth-ionosphere waveguide, forcing them to divert from their regular propagation patterns, making the remote sensing of the lower Ionosphere using the ground-based network of stations as a research method of choice for exploration of this region. High-class solar flare events during the last two solar cycles (SCs) and their impacts on the lower ionosphere based on VLF technology were subject of this research. Particular focus was on the strongest among these events, including the September 2017 events, as recorded by VLF station in Belgrade (44.85N, 20.38W), Serbia. For modeling purposes the Long Wave Propagation Capability (LWPC) software was used. Some of the most relevant parameters related to numerical simulations of VLF propagation characteristics under the high-class Solar flare events are given.

Introduction

Ionized constituents within Earth's atmosphere are grouped within several ionospheric layers, with the D-region reaching the altitudes from 50 to 90 km as the lowest one. Properties of ionospheric plasma constituents within these layers are significantly different both in their characteristics, as well as in variation features, ionization processes, spatial and temporal distribution of the concentrations etc. (e.g. Bilitza et al. 2017, Wait and Spies 1964). During perturbed solar conditions related to flare activity, portion of X-ray radiation from released Sun's energy of electromagnetic spectrum causes additional ionization of neutral constituents within the altitude range corresponding to D-region and significantly alters ionization rates compared to these of lower ionospheric ionizing agents during the regular conditions, such as Lyman- α spectral line and cosmic rays (e.g. Whitten and Poppoff 1965, Hargreaves 1992, Thomson et al. 2021). As a consequence of such increased additional ionization, electron densities within this region are increased as well (Mitra et al. 1974), directly affecting subionospheric Very Low Frequency (VLF) signal transmission that is otherwise stable under the regular ionospheric conditions (e.g. Budden 1988, Thomson 1993, McRae and Thomson 2000). However, it is important to note that D-region, as the closest one to the Earth's surface, in addition to extraterrestrial influences, is also directly affected by different terrestrial processes as well (review of some of the major drivers and also regarding the possibilities of VLF methodology application for such purposes can be found in e.g. Silber and Price 2017).

Since released from U. S. military into the public sector in the late 90s, Long Wave Propagation Capability (LWPC) software (Ferguson et al. 1998), has a long history of successful applications for numerous and diverse purposes related to lower ionospheric explorations. Employing real measurements originating from VLF technology, as a remote sensing technique on one hand, and relaying on Wait's theory (Wait and Spies 1964, Wait 1970) on the other, this numerical method has been widely utilized and is proven as a reliable method for indirect obtaining of lower ionospheric parameters (e.g. Thomson et al. 2005, McRae and Thomson 2004, Žigman et al. 2023, Grubor et al. 2008, Nina et al. 2018, Kolarski et al. 2022, 2023, Kumar and Kumar 2018, Šulić and Srećković 2014, Srećković et al. 2021, Chowdhury et al. 2021, Bekker et al. 2021 etc.).

High-class solar flares (SFs) of X-class, from period covering 23rd – 25th solar cycle (SC) were examined, in terms of their influence on the lower ionosphere electron density changes, indirectly through retrieving of VLF parameters of subionosphericaly propagating radio signals, as recorded by different ground-based stations globally positioned and as observed on VLF signals with different Great Circle Paths (GCPs). Focus was placed on the strongest events, among which these from September 2017, as recorded by Belgrade VLF station (44.85N, 20.38W) in Serbia, are given in more detail. For simulation of both unperturbed and perturbed lower ionospheric conditions due to X-class SFs, LWPC numerical modeling procedure was applied.

Analysis and results

X-class SFs are events with X-ray irradiance greater than 10^{-4} Wm^{-2} and are the most powerful SF events within current classification (that groups all events from A- being the smallest to X- being the largest class). In general, X-class SFs are more common in appearance around periods of solar maximum or ascending and/or descend intervals near maximum of SC, compared to other periods as these related to minimum of solar activity.

However, one of the examples that powerful SF events can occur regardless the stage within the cycle of solar activity are exactly the examples of SFs from September 2017 (Figure 1), when within just a few days several intense SFs ranging from M5.5 to X9.3 occurred inspire the fact that SC progression was in descending stage getting close to the minimum of solar activity (which took place in December 2019) between 24th and 25th - i.e the current SC. During September 2017, 4 X-class SFs in range X1.3 – X9.3 occurred on 6th, 7th and 10th, while 2 high M-class events of M7.3 and M8.1occurred on 7th and 8th September 2017. It is of significance to point out that X9.3 event from 6th September 2017 was the strongest SF within 24th SC. An overview of high X-class (≥X5.0) SF events in period of last two SCs are given in Table 1, as for the sake of visibility are listed by the year of their occurrence rather than their intensity, which is indicated in separate columns on the left. During current SC, there were no high X-class SF events reported as per 15th August 2023. Lower to moderate X-class (X1-X4.9) SF events from 23rd to 25th SC are given in Table 2, including data ending with 15th August 2023, as well. September 2017 events are emphasized in bold font. According to National Oceanic and Atmospheric Administration (NOAA), solar X-ray xlux data were obtained from the Geostationary Operational Environmental Satellite (GOES) Network database.

Response of the lower ionosphere to influence of intense SF events of X-class is modeled based on propagation parameters of VLF radio signals, known as Wait's parameters: effective reflection height *H’* (km) and reflection height sharpness β (km^{-1}), used for calculation of corresponding electron densities *Ne* (m^{-3}) within D-region altitude range, using equation obtained based on Wait′s theory which applies for daytime ionospheric conditions:

$$Ne(z, H', \beta) = 1.43 \cdot 10^{13} \cdot e^{-0.15H'} \cdot e^{(\beta-0.15)(z-H')}. \quad (1)$$

Wait's parameters *H’* (km) and β (km^{-1}) in function of X-ray flux soft component, as measured by GOES satellite probes, for different cases of high-class SFs, with X-class region marked by shaded gray area, are given in Figures 2 and 3. Estimated corresponding electron densities *Ne* (m^{-3}) in function of X-ray flux soft component, indirectly obtained by the use of numerical modeling procedure employing LWPC software by modeling of propagation parameters of VLF signals, are given in Figure 4 (X-class region is also marked by shaded gray area. Results corresponding to output from numerical modeling conducted in this research and related to events from 6th September 2017, are presented by black stars. Wait's parameters β (km^{-1}) and *H’* (km), obtained through numerical modeling procedure, that correspond to peaks of X-ray fluxes of analyzed SFs changed as follows: for X2.2 SF ↑Δβ = 0.13 km^{-1} and ↓Δ*H’* = 14 km and for X9.3 SF ↑Δβ = 0.25 km^{-1} and ↓Δ*H’* = 15.6 km, compared to pair of predefined unperturbed values of (β; *H’*) = (0.3; 74) characteristic for daytime ionospheric regular conditions. Based upon conducted calculations for entire altitude range of D-region, *Ne* for analyzed SFs differs within one order of magnitude throughout the entire D-region. At reference height of 74 km, compared to regular ionospheric conditions, in case of X2.2 SF *Ne* shoved increase by almost 3 and in case of X9.3 SF about 3.5 orders of magnitude.

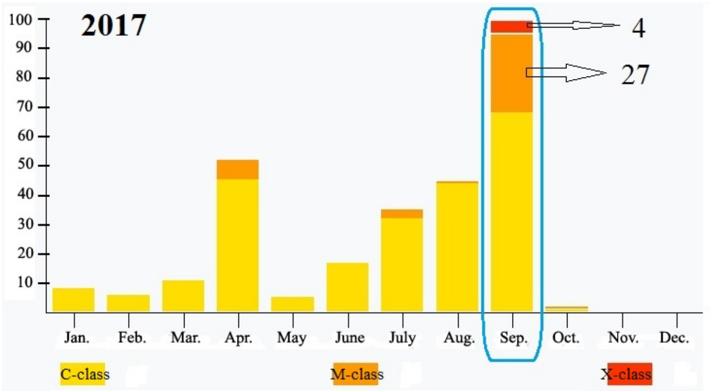

Fig. 1. SFs occurred during 2017, with September events highlighted by blue oval: 4 X- and 27 M-class SFs were reported according to NOAA.

Table 1. SFs of higher X-class (≥X5.0) from 23rd to 25th* SC.

X-class SFs	SC 23: Aug. 1996 – Dec. 2008 (left: strength in SC, right: SF)		SC 24: Dec. 2008 – Dec. 2019 (left: strength in SC, right: SF)	
	7	X9.4; 1997-11-06; 11:55UT		
	14	X5.7; 2000-07-14; 10:24UT		
	2	X20+; 2001-04-02; 21:51UT		
	5	X14.4; 2001-04-15; 13:50UT		
	13	X6.2; 2001-12-13; 14:30UT		
	15	X5.6; 2001-04-06; 19:21UT	3	X6.9; 2011-08-09; 08:05UT
≥X5.0	18	X5.3; 2001-08-25; 16:45UT	4	X5.4; 2012-03-07; 00:24UT
	1	X28+; 2003-11-04; 19:53UT	1	**X9.3; 2017-09-06; 12:02UT**
	3	X17.2+; 2003-10-28; 11:10UT	2	**X8.2; 2017-09-10; 16:06UT**
	6	X10; 2003-10-29; 20:49UT		
	9	X8.3; 2003-11-02; 17:25UT		
	17	X5.4; 2003-10-3; 08:35UT		
	4	X17+; 2005-09-07; 17:40UT		
	10	X7.1; 2005-01-20; 07:01UT		

	12 16 8 11	X6.2; 2005-09-09; 20:04UT X5.4; 2005-09-08; 21:06UT X9; 2006-12-05; 10:35UT X6.5; 2006-12-06; 18:47UT		

* Including data ending with 2023-08-15: no ≥X5 class SFs in SC 25

Table 2. SFs of lower to moderate X-class (X1-X4.9) from 23rd to 25th* SC.

1997: 2 SFs in range X2.1-X2.6 1998: 14 SFs in range X1-X4.9 1999: 4 SFs in range X1.1-X1.8 2000: 16 SFs in range X1-X4 2001: 16 SFs in range X1-X3.4 2002: 11 SFs in range X1-X4.8 2003: 15 SFs in range X1-X3.9 2004: 12 SFs in range X1-X3.6 2005: 14 SFs in range X1.1-X3.8 2006: 2 SFs in range X1.5-X3.4	SC 23: Aug. 1996 – Dec. 2008
2011: 7 SFs in range X1.4-X2.2 2012: 6 SFs in range X1.1-X1.8 2013: 12 SFs in range X1-X3.3 2014: 16 SFs in range X1-X4.9 2015: 2 SFs in range X2.2-X2.7 **2017: 2 SFs in range X1.3-X2.2**	SC 24: Dec. 2008 – Dec. 2019
2021: 2 SFs in range X1-X1.59 2022: 7 SFs in range X1-X2.2 2023: 11 SFs in range X1-X2.28	SC 25: Dec. 2019 – first half 2034 (pred.)

* Including data ending with 2023-08-15

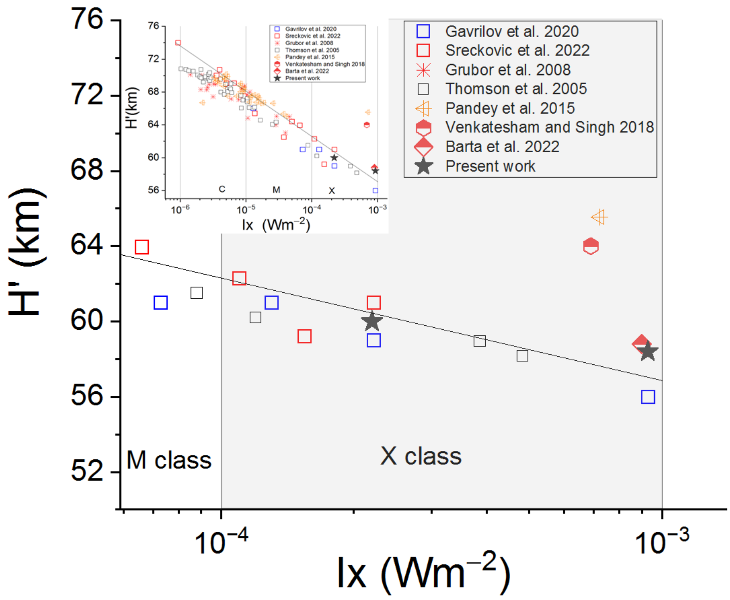

Fig. 2. Parameter *H'* (km) in function of X-ray flux soft component.

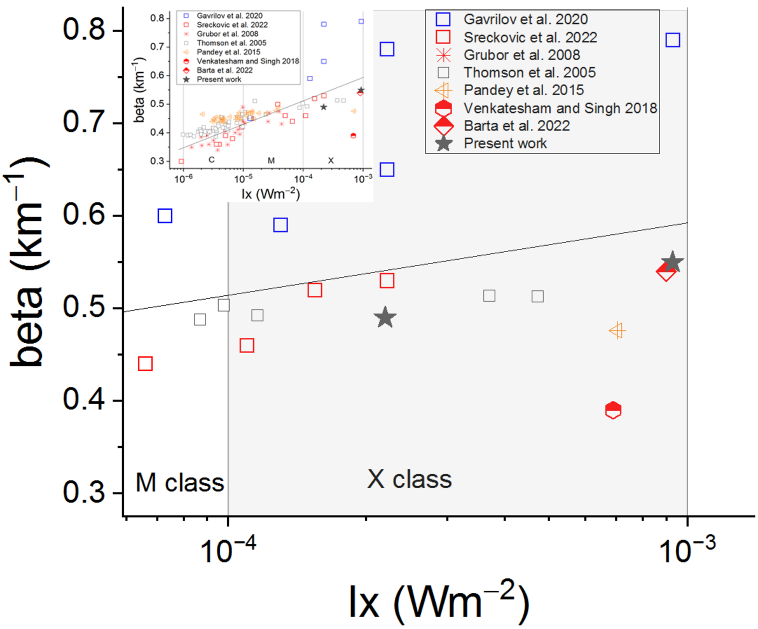

Fig. 3. Parameter β (km^{-1}) in function of X-ray flux soft component.

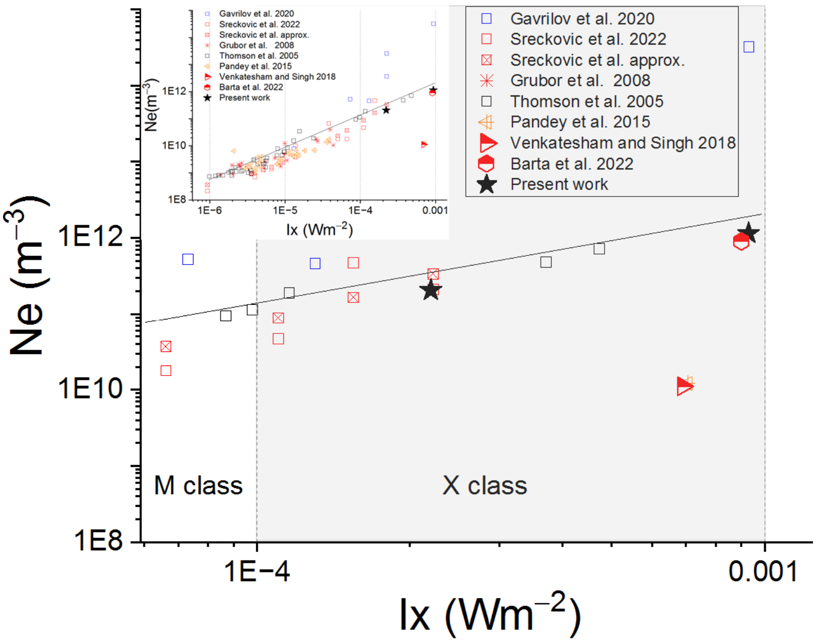

Fig. 4. Estimated electron densities *Ne* (m^{-3}), obtained based on conducted numerical modeling procedure, in function of X-ray flux soft component.

Discussion and conclusions

Modeling of high-class SF events is a challenging task, due to their high strength that usually mirrors itself onto lower ionospheric response through a large scale VLF signal perturbations, which are not easily modeled using numerical procedure employing LWPC software package, especially taking into consideration LWPC software limitations related to waveguide border boundaries. Results from this research regarding Wait's parameters and estimated electron densities related to one weak X2.2 and other strong X9.3 X-class SF occurred on 6^{th} September 2017 were compared with results available from other studies dealing with major cases of strong SFs across three past SCs. Comparison is done for period 2003-2011 including SF cases of class X28+ – X6.9 (1-4) and with some other cases from period 2006-2017 covering range X1 – X9.3 (5-9) and from period 1994-1998 in range X1 – X5 (10), recorded by equipment located in different latitudinal sectors:

1) X6.9 of 09-08-2011 at 08:05UT – strongest SF of 24^{th} SC, associated with CME and SPE events; at low-latitude site in India: values of obtained Wait's parameters H'=~64.0 km and β=~0.39 km^{-1}, which decreases H' by 10 km, and increases β by 0.09 km^{-1}, compared to unperturbed conditions (Venkatesham

and Singh 2018) and *H'*=65.7 km and β=0.48 km^{-1}, compared unperturbed values of *H'*=71.0 km and β=0.43 km^{-1} (Pandey et al. 2015).

2) X9 of 05-12-2006 at 10:35UT – strongest SF in 2006 and eighth of 23rd SC; at mid-latitude site - Belgrade VLF database: values of obtained Wait's parameters related to X9 are *H'*=58.8 km and β=0.54 km^{-1}, electron density changes reach even 3 orders of magnitude at height of 70 km. (Barta et al. 2022).
3) X28+ of 04-11-2003 at 19:53UT – one of strongest solar flares ever recorded and strongest of 23rd SC associated with CME and SPE events, from very active period October 20th - November 5th, 2003 including X10.1 of October 29th, 2003 at 20:49UT and X8.3 of November 2nd, 2003 at 17:25UT third and fourth in 2003 and sixth and ninth of 23rd SC, both associated with CME; at mid-latitude site at Dunedin, New Zealand: values of obtained Wait's parameters related to X28+ are *H'* had lowered to a height of about 53 km, or about 17 km below value of *H'*=71 km typical for unperturbed conditions and β increased up to about 0.57 compared to unperturbed value of β=0.39 km^{-1}. These results were obtained through analysis of a series of SFs from the same very active solar period from 20-10-2003 to 05-11-2003, that included X28+ of 04-11-2003 at 19:53UT, X17.2 of 28-10-2003 at 11:00UT and X10 of 29-10-2003 at 20:49UT and also X8.3 on 02-11-2003 at 17:25UT, and X5.4 on 23-10-2003 at 08:35UT, and X3.9 on 03-11-2003 at 09:55UT. Also were included SF events X20+ of 02-04-2001 at 21:51UT, X9.4 of 06-11-1997 at 11:55UT and X1.3 on 27-05-2003 at 23:07UT, 06-11-1997 (X9), 18-08-1998 (X5), 14-07-2000 (X6), 2-, 6- and 15-04-2001 (X20, X5.6, X14), 28-08-2001, 13-12-2001 (X5, X6) and 23-07-2002 (X5). Events X17.2+ of 28-10-2003 at 11:10UT and X14.4 of 15-04-2001 at 13:50UT were excluded due to receiver location (Thomson et al. 2005).
4) X7.1 of 20-01-2005 at 07:01UT – second strongest SF in 2005 and tenth of 23rd SC associated with CME and SPE events, from active period January 15th–22nd, 2005; at mid-latitude site - Belgrade VLF database: obtained Wait's parameters related to X7.1 depend on signal GCP, *H'* descended for 7 km and *Ne* increased for 2 orders of magnitude compared to regular conditions (unperturbed values of 74 km and $2.16\cdot10^{8}$ m^{-3}) (Grubor et al. 2007), β=0.6 km^{-1} and *H'*=70 km corresponding to *Ne* increase of about 1.5 orders of magnitude compared to unperturbed midday conditions (Kolarski and Grubor 2021) and β=0.38 km^{-1} and *H'*=61 km with *Ne*(74)~$2\cdot10^{10}$ m^{-3} (Žigman et al. 2023).
5) X1.1-X2.2 of 10- and 11-06-2014 (CME?) & X17.2 of October 28th, 2003 (associated with CME and SPE events); at mid-latitude site - Belgrade VLF database: values of obtained Wait's parameters related to X2.2 of 2014-06-10 at 11:42UT are β=0.52 km^{-1} and *H'*=59.2 km with *Ne*=$4.75\cdot10^{11}$ m^{-3}, for X1.5 of 2014-06-10 at 12:52UT are β=0.53 km^{-1}, *H'*=61.0 km with *Ne*=$2.12\cdot10^{11}$ m^{-3}, for X1.1 of 2014-06-11 at 09:06UT are β=0.46 km^{-1}, *H'*=62.3 km and Ne=$4.70\cdot10^{10}$ m^{-3} and for X17.2 of 2003-10-28 at 11:10UT *Ne* was estimated as reaching value of about $0.7\cdot10^{13}$ m^{-3} (Srećković et al. 2021).

6) X1.3 of 07-09-2017; at mid-latitude site - Belgrade VLF database: values of obtained Wait's parameters related to X1.3 are β=0.42 km^{-1}, *H'*=63 km and *Ne* increased almost two orders of magnitude compared to the regular value at altitude 74 km (Kolarski et al. 2022).
7) X1.3-X9.3 of 10-06-2014 and 6- to10-09-2017, with strongest two of them (both above X5) associated with CME; at mid-latitude site at Mikhnevo in Russia, a bit northward from Belgrade and for hard component of X-ray flux: values of obtained Wait's parameters *H'* ranged about from 56 to 74.5 km and β ranged about from 0.27 to 0.87 km^{-1} (Gavrilov et al. 2020).
8) X1.5 of 14-12-2006 at 22:15UT; at low-latitude site in India: values of obtained Wait's parameters related to X1.5 depending on observed GCP are *H'*=59.6 km, β=0.512 km^{-1} and *H'*=61.6 km, β=0.516 km^{-1} compared to unperturbed conditions of *H'*=70.7 km, β=0.390 km^{-1} and *H'*=71.0 km, β=0.390 km^{-1} with estimated decrease in *H'* of 11.1 and 9.4 km and an increase in β of 0.122 and 0.126 km^{-1} (Kumar et al. 2015).
9) X1-X3.2 in period May–December 2013, all associated with CME and one of the weaker ones associated with SPE; at low-latitude site in Vietnam: values of obtained Wait's parameters for all cases of SFs are β increased from 0.3 to 0.506 km^{-1}, while *H'* decreased from 74 to 60 km (Tan et al. 2014).
10) X3-X5 in period 1994-1998, some associated with CME and SEP events; at mid latitude site at Dunedin, New Zealand: values of obtained Wait's parameters related to X3.0 estimated a decrease in *H'* of 12 km and an increase in β of 0.13 km^{-1} relative to their normal daytime values, from 71 to 59 km and from 0.39 to 0.52 km^{-1}, while for X5 is estimated decrease in *H'* of 13 km and the same increase in β (from 71 to 58 km and from 0.39 to 0.52 km^{-1} (McRae and Thomson 2004).

Results from this study, related to high-class SFs, fit well to the general linear trend across entire C–X-class range of X-ray SFs, obtained through numerical modeling based on VLF signal subionospheric propagation monitored on short path signals and recorded by Belgrade VLF station in wide time period, covering 14 years (from 2003 to 2017). These results are in line with results obtained by other research groups dealing with VLF data recorded in other mid-latitudinal sectors with similar position as Belgrade station. However, for some cases of X-class events, there is evident significant discrepancy in obtained results, probably due to latitudinal factor (like these reported by Pandey et al. 2015, Gavrilov et al. 2020 and Venkatesham and Singh 2018). Ionospheric response to analyzed high-class SF events from September 2017 was dramatic, in terms that estimated electron density in peaks of X-ray flux for both events exceeded its regular value for several orders of magnitude at the arbitrary height of 74 km, with about one order of magnitude difference within entire D-region altitude range between the weaker and the stronger SF event. Modeled ionospheric parameters of sharpness and effective reflection height, as well as estimated electron densities for analyzed cases of X-class SF events are in correlation with X-ray flux soft component released during these SFs, as recorded by GOES satellites.

Acknowledgments

This work was funded by Institute of Physics Belgrade, University of Belgrade, through grant by the Ministry of Science, Technological Development and Innovations of Republic of Serbia. Thanks are to D. Šulić for instrumental setup.

References

Barta, V., Natras, R., Srećković, V., Koronczay, D., Schmidt, M., Šulic, D., 2022, Front. Environ. Sci., 10.

Bekker, S. Z., Ryakhovsky, I. A., Korsunskaya, J. A., 2021, J. Geophys. Res. Space Phys., 126.

Bilitza, D., Altadill, D., Truhlik, V., Shubin, V., Galkin, I., Reinisch, B., Huang, X., 2017, Space Weather, 15, 418–429.

Budden, K. G., 1988, The propagation of radio waves, Cambridge Univ. Press UK.

Chowdhury, S., Kundu S., Basak, T., Ghosh S., Hayakawa, M., Chakraborty S., Chakrabarti, S. K., Sasmal, S., 2021, ASR, 67, 1599–1611.

Ferguson, A. J., 1998, Computer program for assessment of long-wavelength radio communications, Version 2.0., Technical document 3030, Space and Naval Warfare Systems Center, San Diego CA 92152-5001, USA.

Gavrilov, B. G., Ermak, V. M., Lyakhov, A. N., Poklad, Y. V., Rybakov, V. A., Ryakhovsky, I. A., 2020, Geomagn. Aeron., 60, 747-753.

Grubor, D. P., Šulić, D. M., Žigman, V., 2008, Ann. Geophys., 26, 1731–1740.

Grubor, D., Šulić, D., Žigman, V., 2007, Proceedings of the IUGG XXIV General Assembly, Perugia, Italy, July 2-13 2007.

Hargreaves, J. K., 1992, The solar-terrestrial environment, Cambridge Univ. Press.

Kolarski, A., Srećković, V. A., Mijić, Z. R., 2022, Appl. Sci., 12, 582.

Kolarski, A., Veselinović, N., Srećković, V. A., Mijić, Z., Savić, M., Dragić, A., 2023, Remote Sens., 15, 1403.

Kolarski, A., Grubor, D., 2021, Proceedings of the The XIX SERBIAN ASTRONOMICAL CONFERENCE, Belgrade, Serbia, October 13-17 2020, 387-390.

Kumar, A., Kumar, S., 2018, EPS, 70-29.

Kumar, S., Kumar, A., Menk, F., Maurya, A. K., Singh, R., Veenadhari, B., 2015, J. Geophys. Res. Space Phys., 120, 788-799.

McRae, W. M., Thomson, N. R., 2000, JASTP, 62, 609–618.

McRae, W. M., Thomson, N. R., 2004, JASTP, 66, 77–87.

Mitra, A. P., 1974, Ionospheric effects of solar flares. Astrophysics and Space Science Library, vol. 46, D. Reidel publishing Company, Boston, USA.

Nina, A., Čadež, V. M., Bajčetić, J., Mitrović, S. T., Popović, L. C., 2018, Sol. Phys., 293, 64.

NOAA National Centers for Environmental Information. Available online: https://satdat.ngdc.noaa.gov/sem/goes/data/avg/ (accessed on 15 August 2023).

Pandey, U., Singh, B., Singh, O. P., Saraswat, V. K., 2015, Astrophys. Space Sci., 357, 35.

Silber, I., Price, C., 2017, Surv. Geophys., 38(2), 407–441.

Srećković, V. A., Šulić, D. M., Ignjatović, L., Vujčić, V., 2021, Appl. Sci. 11, 7194.

Šulić, D., Srećković, V. A, 2014, SAJ, 188, 45-54.

Tan, L. M., Thu, N. N., Ha, T. Q., Marbouti, M., 2014, IJRSP, 43, 197-246.

Thomson, N. R., 1993, JASTP, 55 (2), 173–184.

Thomson, N. R., Clilverd, M. A., Brundell, J. B., Rodger, C. J., 2021, J. Geophys. Res. Space Phys., 126.

Thomson, N. R., Rodger, C. J., Cliverd, M. A., 2005, JGR, 110, A06306.

Thomson, N. R., Rodger, C. J., Clilverd, M. A., 2011, JGR, 116, 11305–11310.

Venkatesham, K., Singh, R., 2018, Curr. Sci., 114, 1923-1926.

Wait, R. J., 1970, Electromagnetic Waves in Stratified Media, Pergamon Press, Oxford, UK.

Wait, R. J., Spies, K. P., 1964, Characteristics of the Earth-Ionosphere waveguide for VLF radio waves, NBS Technical Note 300, USA.

Whitten, R. C., Poppoff, I. G., 1965, Physics of the Lower Ionosphere, Englewood Cliffs, N.J. Prentice-Hall, USA.

Žigman, V., Dominique, M., Grubor, D., Rodger, C.J., Clilverd, M.A., 2023, JASTP, 247, 106074.

Progress Reports

Spectroscopic method for nitrogen impurity estimation in helium atmospheric discharge

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Nonthermal atmospheric pressure discharges have recently emerged as the most investigated and most promising laboratory plasma sources. In the last two decades they have been extensively studied both theoretically and experimentally (see e.g. Brandenburg, 2019). These discharges are predominantly dielectric barrier discharges operating in noble gases. It was shown in several articles that presence of gas impurities within the working gas can be crucial for barrier discharge operation, in some cases even for providing its sustenance. Numerous models have shown the influence of gas impurity level on discharge parameters (see e,g. Martens et al. 2010, Wang and Wang 2005, Zhanf et al. 2019). Therefore, the knowledge of impurity level is required both in experimental work and for designing facilities. Non-invasive methods for gas impurity measurement are preferable. However, measurement of gas impurity using optical spectroscopy is a difficult task, due to the complex processes of production and excitation of emitters.

Here we will present a novel spectroscopic method for estimating the nitrogen molecular impurity in discharge operating in helium. This is a typical working gas/impurity combination - due to low cost of helium on the one hand, and air leakage into the chamber and gas supply system. Furthermore, a certain amount of air impurities is always present in the gas supply cylinder. The method is based on the intensity ratio of prominent nitrogen molecular band and strong helium line. Namely the N_2 ($C^3\Pi u$–$B^3\Pi g$, 0-0) at 337 nm, and the HeI (3^3S-2^3P) at 706 nm were chosen. A collisional-radiative model was developed, and a functional dependance of intensity ratio on impurity at a given reduced electric field was numerically obtained.

In connection, an experimental study was performed to investigate the influence of gas flow rate on a helium dielectric barrier discharge (Ivković et al. 2022). The experiment was concentrated on the presumed connection between the gas flow rate and the impurity level, and consequential change of the discharge operation. A closed-chamber barrier discharge with plane electrodes was examined for a set of gas flow rates. Using the abovementioned spectroscopic method, a strongly non-linear decrease of impurities concentration with increasing flow rate of the working gas was observed.

References

Brandenburg, R. et al., 2019 Plasma Process. Polym. 16, 1

Ivković, S. S., Cvetanović, N., Obradović, B.M. et al 2022 Plasma Sources Sci. Technol. 31 095017

Martens, T., Bogaerts, A., Brok, W. J. M. and Van Dijk, J., 2010, Appl. Phys. Lett. 80 091501

Wang, Y. and Wang, D., 2005,12 023503

Zhang, Y., Ning, W. and Dai, D., 2019 J. Phys. D. Appl. Phys. 52 045203

The close vicinity ions as modifiers of the mean form of cut-off potential: simple approach

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There is a need for correct broadening mechanisms for the investigated models of dense plasmas. The simplest method for describing a close ion coulomb field as well as temperature influence is sort of close vicinity dense packing. The complex ions are treated within the cut-off potential model that is selected as a first candidate for this approach. The ions in dense plasma possess a potential energy comparable or several tens of times stronger than kinetic, thermal energy. In such conditions it is a fair estimate that ions in such plasma form relatively stiff structures. Within this frame a first order estimate is to consider a static ionic structure with thermal energy of ions influencing only mean inter-ionic distance. Alongside with this the far ions are screened and as such only a close vicinity ionic field is needed to be calculated more accurately, while further range ions, when needed, could be considered as point ones. The work on obtaining adequate broadening profiles based on the assumptions of dense strongly coupled plasma are carried out.

Alternative Evaluation Metrics for Machine Learning Model Selection in Ionospheric VLF Amplitude Data Exclusion

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When applying machine learning (ML) methods to classify ionospheric VLF amplitude data for data exclusion, there is a significant imbalance in the ML task. Specifically, the proportion of non-anomalous data to anomalous data is 85- 15% in our example. Commonly used ML evaluation metrics include accuracy, precision, F-measure, recall (Powers, 2020) among others. Standard evaluation metrics for imbalanced ML tasks can yield subpar results, requiring careful interpretation in relation to the distribution of the test dataset. This communication attests to the selection of the Random Forest (RF) model and discusses the inclusion of additional evaluation metrics, including Youden's J statistic, Markedness, General Performance Score (GPS) (De Diego et al. 2022), and Unified Performance Measure (UPM) (Redondo et al. 2020). According to Youden's J statistic, Markedness, GPS, and UPM, the previously selected model with 100 trees is the best overall model, with values of 0.692, 0.673, 0.776, and 0.833, respectively. Furthermore, the interpretation suggested that there was little difference between the models, which is supported by the additional evaluation metrics (the biggest discrepancy can be seen in Markedness at 2.1%). However, the model with 100 trees had the highest evaluation metric values and the fewest (hyper)parameters, making it the most preferable option. Additional evaluation metrics should be incorporated in further research on the utilization of ML methods for automating data exclusion, which will provide a more comprehensive understanding of the model.

References

De Diego, I. M., Redondo, A. R., Fernández, R. R., Navarro, J. and Moguerza, J. M., 2022. General Performance Score for classification problems. *Applied Intelligence*, *52*(10), pp.12049-12063.

Powers, D. M., 2020. Evaluation: from precision, recall and F-measure to ROC, informedness, markedness and correlation. *Journal of Machine Learning Technologies,* 2(1), pp. 37-63.

Redondo, A. R., Navarro, J., Fernández, R. R., de Diego, I. M., Moguerza, J. M. and Fernández-Muñoz, J. J., 2020. Unified performance measure for binary classification problems. In *International Conference on Intelligent Data Engineering and Automated Learning* (pp. 104-112). Cham: Springer International Publishing.

Aerosol vertical profiles in Belgrade, Serbia, associated with different surface PM10 concentrations

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The height of the atmospheric boundary layer (ABLH) is an important parameter in studies of air pollution, as it determines the volume available for dispersion of pollutants. Aerosol lidar provides information on temporal changes of ABLH (using aerosols as tracers) and vertical structure of aerosol layer. Coupled with measurements of meteorological parameters, this information is valuable in interpretation of particulate matter (PM) observations at ground level. Knowledge of the temporal changes of aerosol vertical profile is helpful in understanding the formation of PM air pollution and the impact of long-range transport to surface PM concentrations.

Aerosol lidar measurements performed in Belgrade during 2018-2020, were used to derive vertical profiles of aerosol backscatter coefficient at 355 nm (Klett, 1981; Fernald, 1984) and the temporal evolution of ABLH (Ilić et al., 2018). In this study, selected cases of aerosol layer vertical structure, under different thermodynamic stability conditions of ABL and different levels of PM pollution, are discussed.

References

Fernald, F. G., 1984, Appl. Opt. 23, 652-653.

Ilić, L., Kuzmanoski, M., Kolarž, P., Nina, A., Srećković, V., Mijić, Z., Bajčetić, J. Andrić, M.., 2018, J. Atmos. Sol. Terr. Phys., 171, 250-259.

Klett, J. D., 1981, Appl. Opt., 24, 1638-1643.

Multi-instrumental investigation of extreme space weather events in September 2017: Data and modeling

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Strong Solar activity during September 2017, despite being in the declining phase of cycle 24, produced several solar flares, accompanied by a series of coronal mass ejections that led to complex and geoeffective plasma structures in the heliosphere (Luhmann et al., 2020). These events, involving interactions between plasma structures (Albert et al., 2020), as well as their influence on Earth's environment are very difficult to forecast.

A number of studies used different approaches to analyze influence of Solar activity on particular phenomena either in heliosphere (Kozev et al., 2022, Savić et al., 2023) or ionosphere responses (Kolarski et al., 2022, Srećković at al., 2021). Recently, several investigations based on multi-instrumental measurements and numerical simulations show more comprehensive insight into the ionospheric responses and change of primary cosmic rays' flux due to the extreme Solar activity (Kolarski et al., 2023, Barta et al., 2022).

The focus of this research is to investigate the phenomena induced by the extreme event in near-Earth space and Earth's atmosphere during September 2017, with an emphasis on studying and modeling the variations in cosmic ray flux and disturbances in the lower ionosphere in correlation with Solar activity. The investigation is based on ground-based measurements such as from neutron monitors, very low-frequency (VLF) radio wave stations, and cosmic ray detectors, as well as in situ measurements from different space probes.

The results of this study show that the ionospheric atomic and molecular data like sharpness and effective reflection height and electron density obtained from Belgrade VLF data measurements, are in correlation with incident X-ray flux while time series of cosmic rays' flux measured at Belgrade muon station correspond to disturbance of near-Earth heliospheric conditions.

The multi-instrumental approach accompanied with numerical modeling of specific space weather events additionally contribute to better understanding of solar-terrestrial coupling processes.

References

Albert, D., Antony, B., Ba, Y. A., Babikov, Y. L., et al., 2020, Atoms, 8, 76
Barta, V., Natras, R., Srećković, V., Koronczay, D., et al., 2022, Front. Environ. Sci. 10:904335.
Kolarski, A., Veselinović, N., Srećković, V. A., Mijić, Z., et al., 2023, Remote Sens. 15, 1403
Kolarski, A., Srećković, V. A., Mijić, Z. R., 2022, Appl. Sci. 12, 582
Kozarev, K., Nedal, M., Miteva, R., Dechev, M. and Zucca, P., 2022, Front. Astron. Space Sci. 9:801429.
Luhmann, J. G., Gopalswamy, N., Jian, L. K. et al., 2022, Sol Phys 295, 61
Savić, M., Veselinović, N., Dragić, A., et al., 2023, Adv. Sp. Research, 71,4
Srećković, V. A., Šulić, D. M., Vujčić, V., Mijić, Z. R., et al., Appl. Sci. 2021, 11, 11574

COST programme role within the Serbian multilateral collaboration in science and innovation framework

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COST – Cooperation in Science and Technology is a networking programme fully financed by the European Horizon frameworks (H2020 and HE) with the aim to foster collaboration of researchers and innovators within European countries and to contribute to the creation of European Research Area (ERA). Its main priorities are to promote and spread excellence, to foster interdisciplinary research through breakthrough science and to empower and retain young researchers and innovators. Although COST programme does not finance the research itself (it is lean on the national funding schemas of all 41 participating countries) it enables wide collaboration and networking through general or working group meetings, short term scientific missions, training schools and management meetings.

In 2022 Serbian researchers performed an individual participation in more than 750 COST Action activities. COST Actions generally last for four years, up to now, Serbian researchers chaired and co-chaired 23 Actions and participated in total of 928 Actions (https://www.cost.eu/about/members/serbia/). The broader statistics of Serbian participation in COST Actions can be found in Marinković et al. (2022).

Acknowledgements

Thanks are due to The Ministry of Science, Technological Development and Innovation of the Republic of Serbia and the Institute of Physics Belgrade for national COST office support.

References

Marinković, Bratislav P., Ivanović, Stefan and Mijić, Zoran, “Data analysis on Serbian participation in COST Actions: Celebrating 50 years of research networks”, IV Meeting on Astrophysical Spectroscopy - A&M DATA - Atmosphere, May 30 to June 2, 2022, Fruška Gora, Serbia, Book of Abstracts and Contributed Papers, Eds: V. A. Srećković, M. S. Dimitrijević, N. Veselinović and N. Cvetanović, (Institute of Physics Belgrade, Belgrade, 2022), Progress report, pp.49-57. ISBN: 978-86-82441-57-1

Interdisciplinary research in the European Cooperation in Science and Technology – advantage or disadvantage?

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Collaboration is at the heart of modern science while interdisciplinary research plays a very important role in addressing some of the most important and complex problems. The European Cooperation in Science and Technology – COST is the oldest intergovernmental funding organization in Europe with the aim to establish the research networks among scientists and innovators. Two years ago, COST celebrated 50 years of the existence and successful networking activities. During that period COST has become one of the best mechanisms to promote science cooperation in the world. For establishing a collaboration proximity is particularly important, but once a collaboration is in place scientists manage to continue a collaboration despite a large distance. COST Actions support a variety of networking tools enabling spatial and social proximity thus increasing the level of scientific production.

In this paper review of available data on the effects of participating in a COST Action on the level of scientific production i.e., scientific co-publications between active members of an Action is given (Seeber et al., 2022a). In addition, the interdisciplinary nature of co-publications and involvement of researchers from inclusive target countries as well as young researcher is discussed. Since researcher from Serbia are involved in almost 96% of active Actions (Mijić and Marinković, 2022) it is particularly important to assess whether these effects persist after the life time of the Action.

Regarding the multidisciplinarity of the new Actions approved in 2023, 54% of them cover at least two fields of science and technology, while 11% cover at least three fields. Natural sciences are represented in 49% of the Actions leading the way as the most represented field of science. Therefore, additional discussion will be given for better understanding whether Actions proposals' degree of interdisciplinarity and the relative proportion of different scientific fields, may be disadvantage or not in the project evaluation procedure in the COST research framework (Seeber et al., 2022b).

Acknowledgements

Thanks are due to The Ministry of Science, Technological Development and Innovation of the Republic of Serbia and the Institute of Physics Belgrade for national COST office support.

References

Mijić, Z., Marinković, B., 2022, IV Meeting on Astrophysical Spectroscopy - A&M DATA - Atmosphere, Book of Abstracts and Contributed Papers, Eds: V. A. Srećković, M. S. Dimitrijević, N. Veselinović and N. Cvetanović, pp.74-80.

Seeber, M., Vlegels, J., Seeber, M., 2022a, 26th International Conference on Science and Technology Indicators, Proceedings, Eds: N. Robinson-Garcia, D. Torres-Salinas, W. Arroyo-Machado, sti2239

Seeber, M., Vlegels, J., Cattaneo, M., 2022b, J. Assoc. Inf. Sci. Technol. 73, 1106

Posters

The broadening of carbon spectral lines emitted from a pulsed atmospheric pressure gas discharge source with graphite cathode

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The atmospheric pressure needle-to-cylinder (NTC) gas discharge source operating in pulsed power regime was recently developed and employed for the study of broadened neutral and ionic lines (Ar I, Fe I, Cu I, Cu II) and investigation of ro-vibrational distribution of molecular bands (AlO, CN) (Jovović and Majstorović 2023, Jovović 2023). The numerous (narrow) metallic lines originating from the cathode material (aluminum, brass, stainless steel) are identified which is of importance for metals and alloys spectral lines catalogue (Jovović 2023). The recorded narrow lines are used for electron temperature T_e measurement as well (Jovović 2023). In order to measure Stark halfwidths and shifts of broadened lines, the complex line shape is fitted by a modal function representing the summation of Voigt profiles. For those spectral lines with known Stark broadening parameters, the electron number density N_e in gas discharge regions is obtained while for those lines with unknown parameters, such as Cu II 565.1 nm line, the electron impact halfwidth can be estimated from the fitting function.

Using the same methodology, the spectra of C I and C II lines, recorded with spectrometer-CCD camera setup from the NTC gas discharge source with graphite cathode in argon, are analyzed. The experimental Stark halfwidths and shifts can be found in various references (see e.g., Konjević and Wiese 1976, Konjević et al. 1984, Mijatović et al. 1995). Since the gas temperature T_g is an important parameter for the calculation of Doppler and pressure broadening halfwidths, several well resolved C_2 molecular bands with $\Delta v=0, 1, -1, -2$ are recorded and, in conjunction with molecular data, T_g measured. The N_e and T_g results will be presented and the comparison with brass and stainless steel cathode NTC gas discharge parameters will be shown.

References

Jovović J., Majstorović, G. Lj., 2023, Contrib. Plasma Phys., 63 (1), e202200058.
Jovović J., 2023, J. Anal. At. Spectrom., DOI: 10.1039/d2ja00429a.
Konjević N., Wiese N. L., 1976, J. Phys. Chem. Ref. Data, 5 (2), 259.
Konjević N., Roberts J. R., 1976, J. Phys. Chem. Ref. Data, 5 (2) 209.
Mijatović Z., Konjević N., Kobilarov R., Djurović S, 1995, Phys. Rev. E, 51 (1) 613.

Transport properties of H_2^+ ions in H_2 gas

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Cold plasmas are frequently used in new technologies where they open up possibilities of non-intrusive production or modification of various substances (Makabe and Petrović, 2006). These plasmas have a high electron temperature and low gas temperature, so the non-equilibrium behavior of a large number of species becomes important (Robson et al., 2005).

In this work we present a complete cross sections set and transport properties of H_2^+ in H_2 gas. Ionic charge transfer reactions with molecules are indispensable elementary processes in the modeling of kinetics in terrestrial, industrial and astrophysical plasma in the detection of dark matter (Kaboth et al., 2008). A Monte Carlo simulation method is applied to accurately calculate transport parameters in hydrodynamic regime. We discuss new data for H_2^+ ions in H_2 gas where the mean energy the flux and bulk values of reduced mobility and other transport coefficients are given as a function of low and moderate reduced electric fields *E/N* (*E*-electric field, *N*-gas density).

References

Kaboth A., Monroe J., Ahlen S., Dujmić D., Henderson S., Kohse G., Lanza R., Lewandowska M., Roccaro A., Sciolla G., Skvorodnev N., Tomita H., Vanderspek R., Wellenstein H., Yamamoto R., Fisher P., 2008, Nucl. Instrum. and Meth. in Phys. Res. A 592, 63

Makabe T., Petrović Z., Plasma Electronics: Applications in Microelectronic Device Fabrication Taylor and Francis, CRC Press, New York, 2006

Robson R. E., White R. D. and Petrović Z. Lj., 2005, Rev. Mod. Phys. 77, 1303

Examination of the ionospheric response to intense solar activity from September 6 to 10, 2017

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The ionosphere is a layer within the Earth's atmosphere that contains charged particles, whose characteristics are influenced by solar, external and other extraterrestrial ionizing factors. The ionosphere is divided into several layers and sublayers depending on their composition and physical characteristics.

Solar flares are strong explosions on the surface of the Sun, which are known to produce additional ionization of the Earth's atmosphere in the sunlit hemisphere. When the energy from the solar flare reaches the Earth, it performs additional ionization in the ionosphere, changing the density and location of its constituents. Extreme ultraviolet EUV radiation is absorbed in the higher altitudes of the E and F regions, while X-rays penetrate deeper into the ionosphere reaching the D region and causing additional ionization and absorption of electromagnetic waves (see e.g. Chowdhury et al. 2020, Barta et al. 2022, Buzas et al. 2023 etc.).

The International Reference Ionosphere (IRI) is a joint venture of the Committee of Space Research (COSPAR) and the International Union of Radio Science (URSI) to develop and improve an international standard for parameters in the Earth's ionosphere. IRI represents the average values of electron and ion densities for the altitude range of 50-2000 km (see Bilitza et al. 2016). In this paper, we examined the response of the ionosphere to intense solar activity in the period September 6-10, 2017. The IRI model was used in this research with the goal to examine the behavior of the ionosphere under the influence of intense solar activity in this specified period. Calculations were performed for M and X-class flares and included three ionosonde stations: Juliusruh (54.6° N, 13.4° E), San Vito (40.6° N, 17.8°E) and Pruhonice (50° N, 14.6° E). The initial modeling parameters used for given stations and periods before and after examined flare events were taken from site https://giro.uml.edu/didbase/scaled.php.

References

Barta, V., 2023, *Front. Astron. Space Sci.*, 10:1201625.

Barta, V., Natras, R., Srećković, V., Koronczay, D., Schmidt, M., Šulic, D., 2022, *Front. Environ. Sci*. 10:904335.

Bilitza, D., Altadill, D., Truhlik, V., Shubin, V., Galkin. I., Reinisch. B., Huang, X., 2017, *Space Weather*, 15, 418–429.

Buzás, A., Kouba, D., Mielich, J., Burešová, D., Mošna, Z., Koucká Knížová, P.,

Chowdhury, S., Kundu, S., Basak, T., Hayakawa, M., Ghosh, S., Chakraborty, S., Chakrabarti, S., Sasmal, S., 2020, *Adv. Space Res.,* 67. 1599-1611.

https://giro.uml.edu/didbase/scaled.php

Collisional and radiative processes involving some small molecules: cross sections and rate coefficients

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Many fields in astronomy such as astrophysics, astrochemistry and astrobiology, depend on data for atomic and molecular collision and radiative processes (Albert et al., 2020; Srećković, et al. 2022). Moreover, in the age of precision astronomy, determining the chemical composition of the early Universe necessitates a precise assessment of the reaction rates of the primary chemical processes involved. Abundances and processes (recombination, destruction, etc.) which involve small molecular ions can play an important role in the modeling such environments (Gnedin et al., 2009; Srećković et al. 2020). Our aim is to obtain theoretically – calculate, compare and analyse cross sections and rate coefficients, i.e., data, about such small systems involving lithium, hydrogen and helium, etc. molecular ions for a wide range of parameters.

Acknowledgments

This work is supported by the Science Fund of the Republic of Serbia, Grant No. 7749560, Exploring ultra-low global warming potential gases for insulation in high-voltage technology: Experiments and modelling EGWIn.

References

Albert, D., et al., 2020, Atoms 8.4, 76.
Gnedin, Yu. N., et al., 2009 New astronomy reviews 53.7-10, 259-265.
Srećković, V. A., et al., 2022, Data, 7.9, 129.
Srećković, V. A., Ignjatović Lj. M., and Dimitrijević M. S., 2020 Molecules 26.1, 151.

ACol – Database for collisional processes

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Atomic and molecular data and databases, especially today, are crucial for creating models and simulations of physical processes as well as for interpreting (big)data gathered from observations and measurements (Albert et al. 2020; Srećković et al. 2020). Models must be updated frequently, incorporating as many processes as possible and utilizing the most precise data (Vujčić et al. 2015; Srećković et al. 2022). Our goal is to participate in this by providing such datasets. In this contribution we present current stage of ACol database. The rate coefficients for excitation/deexcitation and ionization/recombination collisional processes in hydrogen, helium, and alkali plasmas are included in ACol. The database is currently under development. The data could be helpful for researching and modeling LTP as well as weakly ionized layers in various atmospheres.

Acknowledgments

The authors acknowledge the support from the Astronomical Observatory and Institute of Physics Belgrade, which was made possible by grants from the Ministry of Science, Technological Development and Innovations of the Republic of Serbia.

References

Albert, D., et al., 2020, Atoms 8.4, 76.
Srećković, V. A., et al., 2022, Data, 7.9, 129.
Srećković, V. A., Ignjatović, Lj. M., and Dimitrijević, M. S., 2020 Molecules 26.1, 151.
Vujčić, V., et al., 2015, Journal of Astrophysics and Astronomy, 36, 693-703.

Stark polarization spectroscopy in the cathode sheath of a Grimm-type glow discharge in neon

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The quadratic Stark effect occurs in many-electron atoms as a result of an external field-induced electric dipole in an atom, and the lines and their split components in the spectrum are shifted asymmetrically relative to the unshifted zero-field line. As the atomic number rises above hydrogen and hydrogen-like atoms, the quantum mechanical calculations of energy levels become more demanding and involve appropriate approximations verified by experimental results in terms of the number of components detected and their shifts from the unperturbed transition. For a number of argon and neon spectral lines, Windholz 1980, and Jäger and Windholz 1984 identified the numbers and shifts of the Stark components in strong electric fields up to 1000 kV/cm.

We report on the polarization-dependent excitation of five asymmetrically shifted Stark components of neutral neon lines Ne I 503.775 nm [5*d* (7/2) 4 → 3*p* (5/2) 3] and Ne 508.038 nm [5*d* (7/2) 3 → 3*p* (5/2) 2] in the cathode sheath of a Grimm-type DC glow discharge source (GDS), operating in Ne+0.8%H_2 mixture. Optical emission spectroscopy (OES) is applied to study a narrow dark slice of the discharge next to the cathode surface where externally applied voltage produces a linearly decreasing electric field and where ions and electrons are accelerated in opposite directions, resulting in charge-exchange fast neutrals generation, secondary electron emission, and various other elastic and inelastic collisional processes. OES measurements are made at the position in the cathode sheath where a maximum electric field strength of around 15 kV/cm is attained to ensure the largest shifts of Stark components. A linear light polarizer is used to select the polarization-dependent components, i.e., the ones with electric vector linearly polarized in the direction of the external electric field (so-called π components), and ones with electric field vector circularly polarized in the plane perpendicular to the external electric field (σ components), see Fig. 1 and Ryde 1976.

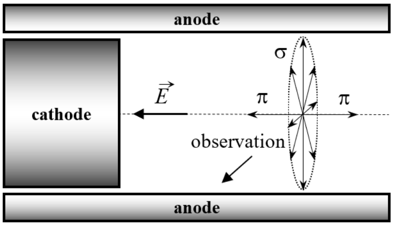

Fig. 1. Central part of Grimm GDS and the schematics of π and σ light polarization.

The OES results are shown in Fig. 2. While the unpolarized profiles (black line/circles) reproduce well Windholz's measurements (1980), which for the 5*d*–3*p* transitions identified 3 Stark components (in addition to the unshifted zero-field line at λ_0), the polarization spectroscopy reveals more complex structure, with 3 shifted σ (red line/triangles) and two π (blue line/squares) components. While Windholz's 1980 study of unpolarized emission is based on the assumption that for noble gasses with Z > 4, the upper transition levels only split and contribute to the excitation of Stark components, the detection of 5 Stark components in total can be explained following Ryde's 1976 considerations that the small splitting of the lower levels occurs too. The apparent energy overlapping of two higher red-shifted σ transitions with both π components, see Fig. 2, indicates the indeed small energy splitting of the lower *p* levels. In the unpolarized profile, the σ and π components show their joint footage, appearing as an integral 3-component structure, detected by Windholz 1980.

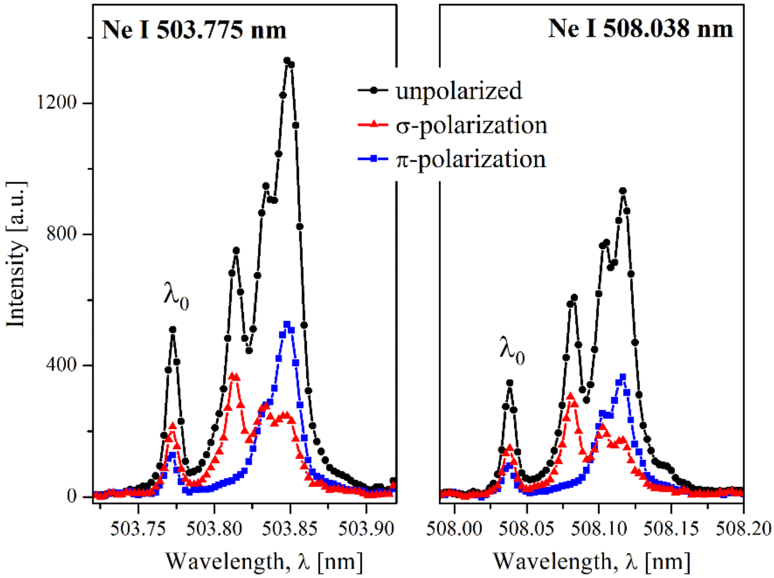

Fig. 2. Unpolarized and polarized profiles of neutral neon Ne I 503.775 nm and Ne I 508.038 nm spectral lines, recorded in the cathode sheath. λ_0 denotes the position of the unshifted line.

References

Jäger, H., Windholz, L., 1984, Phys. Scripta 29, 344
Ryde, N., 1976, Atoms and molecules in electric fields, Almqvist & Wiksell
Windholz, L., 1980, Phys. Scripta 21, 67

Collisional processes involving Rydberg atoms: Rate coefficients

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Ionization processes involving highly excited atoms and molecules in different environments continue to arouse the interest of researchers due to their influence on spectral properties (Albert et al., 2020; Gnedin et al., 2009; Srećković et al. 2023). Here we obtained the data, i.e. the rate coefficients for such processes for wide range of parameters and principal quantum numbers. Our goal is to produce high-quality data that can be properly incorporated into current codes and databases for modeling planetary atmospheres, laboratory plasma, geo-cosmic plasma, the ionosphere, etc.

Acknowledgments

The authors acknowledge the support from the Astronomical Observatory and Institute of Physics Belgrade, which was made possible by grants from the Ministry of Science, Technological Development and Innovations of the Republic of Serbia.

References

Albert, D., et al., 2020, Atoms 8.4, 76.
Gnedin, Yu. N., et al., 2009 New astronomy reviews 53.7-10, 259-265.
Srećković, V. A., et al., 2023, Advances in Space Research, 71(2), 1245-1251.

Impact of strong solar flares on the lower ionosphere: radio waves, satellite observations and modeling

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Solar flare X-ray energy can significantly increase electron density in the Earth's atmosphere (Srećković et al. 2021). This intense solar radiation and activity can cause abrupt ionospheric disturbances, potentially leading to natural disasters (see Kolarski et al. 2022 and references therein). The primary goal of this research is to examine the changes caused by strong solar X-ray flares using very low frequency and low frequency radio signals and satellite observations. The model is used to compute the ionosphere parameters caused by intense solar radiation.

Acknowledgments

The authors acknowledge the support from the Institute of Physics Belgrade, which was made possible by grants from the Ministry of Science, Technological Development and Innovations of the Republic of Serbia.

References

Kolarski, A., Srećković, V. A., and Mijić, Z. R., 2022, Applied Sciences, 12(2), 582.
Srećković, V. A., Šulić, D. M., Vujčić, V., Mijić, Z. R., and Ignjatović, L. M., 2021, Applied Sciences, 11(23), 11574.

Data quality assurance and characterization of Belgrade Raman lidar station

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Atmospheric probing and the observations of atmospheric aerosol particles can be performed remotely with high spatial and temporal resolution using LIDAR (Light Detection And Ranging) technique. Aerosol optical characteristics provide extensive information on the existence and development of atmospheric aerosol structures. As an EARLINET (the European Aerosol Research LIdar Network) (Pappalardo et al., 2014) joining lidar station, Belgrade Raman lidar system has provided aerosol profiling data for potential climatological studies as well as assessment of planetary boundary layer evolution (Ilić et al., 2018) and conducting dedicated measurements during potential airborne hazards events (e.g., volcanic ash, desert dust, biomass burning). To provide a quality controlled and homogeneous analysis of raw lidar data across the network, a centralized analysis tool, called the Single Calculus Chain (SCC), has been released within EARLINET (Mattis et al., 2016). In order to assess the performance and the temporal stability of a lidar system a rigorous quality-assurance (QA) program and self-testing check-up tools have been developed. In this paper a description of the Belgrade Raman lidar system capabilities, and its experimental characterization related to zero bin, analog to photon-counting signal delay, the Rayleigh-fit and telecover tests to check the system accuracy (Freudenthaler et al., 2018) will be presented.

References

Freudenthaler, V., Linné, H., Chaikovski, A., Rabus, D., Groß, S., 2018, Atmos. Meas. Tech. Discuss. preprint, https://doi.org/10.5194/amt-2017-395

Ilić, L., Kuzmanoski, M., Kolarž, P., Nina, A,, et al., 2018, Journal of Atmos. Sol.-Terr. Phys. 171, 250

Mattis, I., D'Amico, G., Baars, H., Amodeo, A., et al., 2016, Atmos. Meas. Tech. 9, 3009

Pappalardo, G., Amodeo, A., Apituley, A., Comeron, A., et al., 2014, Atmos. Meas. Tech., 7, 2389

Multilayer Perception Hyperparameter Fine-Tuning for Ionospheric VLF Amplitude Data Exclusion

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Abstract

The analysis of ionospheric amplitude data is affected by various factors, including the influence of solar flare events, instrument malfunction, and other sources of error. These factors collectively contribute to a decrease in the overall quality of the data. The removal of such data is performed manually by researchers, a process that is characterized by its labor-intensive nature and time-consuming requirements. This research paper presents a procedure for fine-tuning of the learning rate (LR), number of epochs and the momentum in Multilayer Perception (MLP) classification models. The proposed method can be utilized as a benchmark for optimizing other hyperparameters in the future.

Introduction

Very low frequency (VLF) ionospheric amplitude data is adversely affected by solar flare events and instrumental errors, including malfunctions. In order to render the VLF amplitude data applicable for further analyses by researchers, it is imperative to eliminate those effects. The process of manually removing these effects is known to be time-consuming, tedious, and labor-intensive. Consequently, there is an advantage in automating this process using machine learning (ML) classification techniques.

In order to accomplish this task, a range of ML techniques can be utilized, including Artificial Neural Networks (ANN) such as Multilayer Perception (MLP) models, as well as traditional ML models like Random Forests (RF) and Support Vector Machines (SVM). The distinction between MLP models and classic models, such as RF models, becomes evident when considering the quantity of hyperparameters that require configuration. In the case of RF models, the researcher is only required to determine the number of trees. Conversely, MLP models necessitate the fine-tuning of multiple hyperparameters, including the learning rate (LR), momentum, and the number of epochs among others. This study aims to demonstrate the process of fine-tuning the LR, number of epochs and the momentum. This initial step will serve as a starting point in identifying the most suitable MLP model for the intended research objective, which involves the automated identification of erroneous data points in ionospheric VLF amplitude data.

Methods and data

The data employed for this study consists of VLF amplitude measurements obtained during the months of September and October of 2011. These measurements capture solar flare events falling within the range of C2.5 to X2.1 in terms of their class. The training dataset for September 2011 consists of 59,344 datapoints after being balanced as to remove any bias (Prusa et al. 2015; Kulkartni et al. 2020; Devi et al. 2020), while the testing dataset for October 2011 comprises 180,071 data points. The training and testing datasets consist of 40 features, encompassing the original VLF amplitude data, X-ray irradiance data, encoded values of the transmitter and receiver, and the local receiver time expressed in decimal points. Statistical features encompass additional features, including rolling window statistics that employ diverse window lengths (5, 20, and 180 minutes) and varying parameters such as mean, median, and standard deviation. The features utilized in the analysis also consisted of the first and second differential data of both VLF amplitude and X-ray measurements.

The process of searching and optimizing hyperparameters was conducted in a two-step manner. The initial step consisted of determining the optimal combination of the LR and the number of epochs, while maintaining a constant momentum hyperparameter of 0.2. The second phase of the procedure involved determining the optimal momentum value, while keeping the LR and number of epochs constant. In the initial phase, the LR and the number of epochs were subject to variation within the ranges of 0.1 to 0.85 and 100 to 500, respectively. The LR varied by increments of 0.1, while the number of epochs varied by increments of 200. The initial iteration of the modeling process consisted of a total of 18 models, whereas the second stage of modeling involved a total of 9 models. The Weka software package (Frank et al. 2016) included several noteworthy parameters, one of which was the number of nodes. In the case of this MLP, this value was determined by dividing the sum of the number of features and classes by 2, resulting in a total of 22 nodes.

The evaluation of all models involved the utilization of standard ML classification methods, including the F-measure, the area under the receiver operating characteristic curve (ROC), the number of Correctly Classified Instances (CCI), the percentage of Incorrectly Classified Instances (ICI), Cohen's kappa statistics, true positive (TP) and false positive (FP) rates, as well as the Matthew's correlation coefficient (MCC). Due to the inherent imbalance in the ML problem at hand, the analysis primarily emphasized the evaluation of the MCC and kappa values. These metrics were chosen as they offer a less biased assessment of the model compared to other measures like the F-measure for imbalanced datasets (Chicco, Jurman, 2020). Furthermore, the F-measure, TP and FP rates were examined subsequent to the evaluation of MCC and kappa statistics. This analysis included an examination of per-class statistics. The ROC value was additionally analyzed in order to ascertain the models' ability to distinguish between different classes.

Results and Discussion

The preliminary analysis involved conducting modeling tests with different LR values and varying the number of epochs. The resulting MCC values ranged from 0.34 to 0.42. Notably, the model trained with an LR value of 0.85 and 500 epochs achieved the highest MCC value among all the models tested. Furthermore, it is worth noting that the aforementioned model exhibited the highest Kappa coefficient, which was measured at 0.36. The weighted TP rates for all models ranged from 0.659 to 0.745. In contrast, the TP rate for the anomalous data class ranged from 0.94 to 0.73, with the best model achieving a TP rate of 0.843. The average weighted F-measure for all 18 models was found to be 0.753. However, the model that was considered the best overall exhibited a higher weighted F-measure value of 0.774, surpassing the mean value. In general, the model with a LR of 0.85 and 500 epochs exhibited satisfactory evaluation metric statistics. It demonstrated a higher F-measure compared to the average F-measure of all the models, as well as higher values for the MCC and Kappa coefficient.

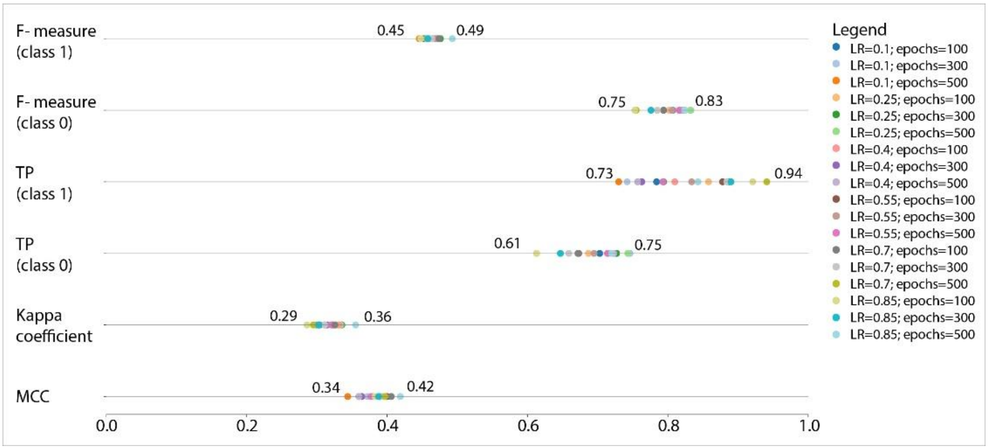

Fig. 1. Evaluation metrics for the first phase of the hyperparameter tuning.

The second iteration of modeling was conducted using a fixed LR and epoch values of 0.85 and 500, respectively. However, the momentum was not constant and varied from 0.1 to 0.9 in increments of 0.1. The observed CCI values exhibited a greater upper limit of 84%. However, the model responsible for generating these outcomes demonstrated inaccurate MCC and Kappa values, rendering it unsuitable for further analysis. As a consequence, the model was excluded from consideration. In contrast, among the models considered in the second round, the model with a momentum value of 0.2, which was also employed in the initial modeling phase, emerged as the best model overall.

The figure depicting the performance of the best overall model (LR= 0.85, trained for 500 epochs and with a momentum of 0.2) was created to illustrate both successful and unsuccessful classifications. Figures 2a and 2b in the upper panels depict the pre-processing outcomes conducted by the researchers, whereas the bottom panels illustrate the display generated by the MLP classification. In the case of the satisfactory classification example, it is evident that the model successfully classified erroneous data points accurately. In the case of the poorer classification example, the model misclassified a significant number of data points that were determined to be non-anomalous and also inaccurately interpreted the duration of the anomaly.

It is important to note that the time intervals depicted in Figure 2 may not be continuous due to the removal of erroneous data points during the pre-processing stage for MLP classification. Additionally, the figure is presented in instances representing minutes of the day rather than in units of time.

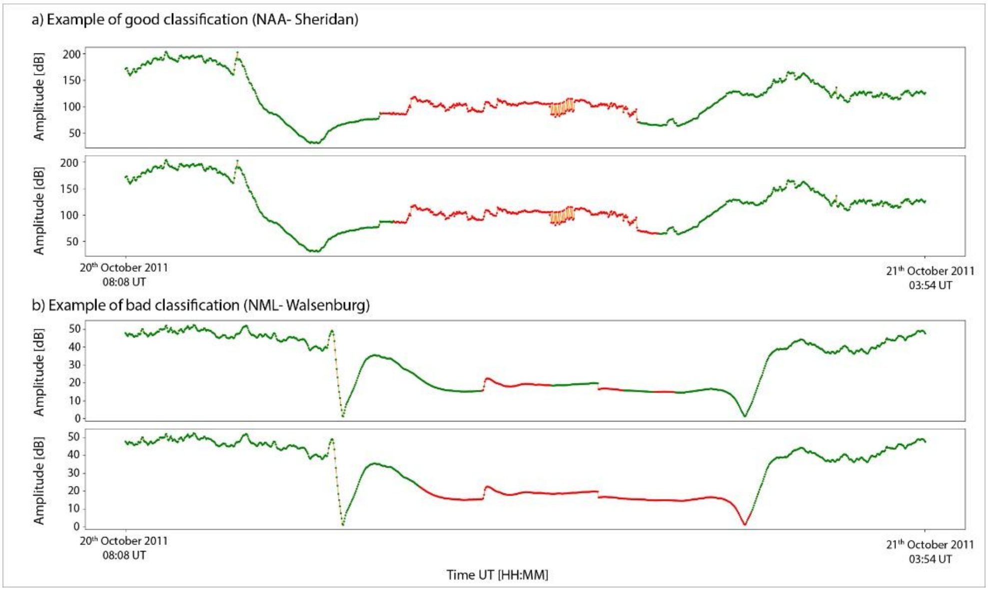

Fig. 2. Examples of good and bad classifications made by the model.

When compared to other ML methods, such as the RF model, the MLP model requires more extensive fine-tuning and computational resources. Consequently, the RF model can be considered a more favorable initial alternative for assessing the suitability and solvability of a given task using ML methods, given the available and used features and data.

Conclusions

Multilayer Perceptron models exhibit the potential for further refinement and future investigation in optimizing additional parameters. The findings suggest that the model with a LR of 0.85, 500 epochs, and a momentum value of 0.2 performed the best among all MLP models evaluated. The model chosen as best and described in the study exhibited the highest MCC and kappa values, as well as F-measure values that surpassed the average value for all models developed.

Once further research has been conducted and fine- tuning have been made, the model can be employed for the purpose of classifying ionospheric VLF amplitudes with supposed high quality. This model can also be used for future comparisons with other models and for the exclusion of future data in the analysis of ionospheric VLF amplitudes.

Acknowledgments

This work was funded by the Institute of Physics Belgrade, University of Belgrade, through a grant by the Ministry of Science, Technological Development and Innovations of the Republic of Serbia.

References

Chicco, D. and Jurman, G., 2020. The advantages of the Matthews correlation coefficient (MCC) over F1 score and accuracy in binary classification evaluation. BMC genomics, 21(1), pp.1-13.

Devi, D., Biswas, S. K. and Purkayastha, B., 2020, July. A review on solution to class imbalance problem: Undersampling approaches. In 2020 international conference on computational performance evaluation (ComPE) (pp. 626-631). IEEE.

Frank, E., Hall, M. A., Witten, I. H., 2016. The WEKA Workbench. Online Appendix for "Data Mining: Practical Machine Learning Tools and Techniques", Morgan Kaufmann, Fourth Edition, 2016.

Kulkarni, A., Chong, D. and Batarseh, F. A., 2020. Foundations of data imbalance and solutions for a data democracy. In Data democracy (pp. 83-106). Academic Press.

Prusa, J., Khoshgoftaar, T. M., Dittman, D. J. and Napolitano, A., 2015, August. Using random undersampling to alleviate class imbalance on tweet sentiment data. In 2015 IEEE international conference on information reuse and integration (pp. 197-202). IEEE.

Classification of Forbush decrease events utilizing machine learning

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The potential existence of two classes of Forbush Decrease (FD) events has already been suggested by the analysis of energetic proton fluence spectra measured at L1 (Savić et al. 2023). We further explore this assumption in the work presented herein.

The most powerful coronal mass ejections, which can lead to Forbush Decreases, often occur during periods of increased solar activity. Coincidentally, such intense phenomena can also result in complex interactions in the heliosphere, where accurate determination of energetic proton fluence may become more difficult. Therefore, in order to increase statistical robustness and reduce uncertainties, we try to expand the classification procedure to include a wider set of various space weather parameters, that are more reliably determined.

The IZMIRAN database of Forbush decreases (IZMIRAN 2021) serves as an online repository, and contains an extensive list of FD events, along with a large number of associated space weather parameters. The idea for the presented analysis is to employ machine learning techniques in an attempt to separate FD events into two assumed classes, using a number of selected parameters from the IZMIRAN database as input variables. We compared the efficiency of different machine learning algorithms using the TMVA package integrated in the ROOT analysis framework (Hocker 2007), and tried to establish the optimal boundary value of FD intensity to be used for separation. The Support Vector machine algorithm (SVM, Cortes 1995) was selected for the analysis based on its overall performance, efficiency and flexibility. Finally, a subset of space weather variables to be used for classification was selected based on their predictive power.

References

Cortes, C., Vapnik, V., 1995, Mach Learn, 20, 273–297.
Hocker, Andreas; 2007, CERN-OPEN-2007-007.
IZMIRAN Space WeatherPrediction Center, 2021
Savić, Mihailo; Veselinović, Nikola; Dragić, Aleksandar, Maletić, Dimitrije; Joković, Dejan; Udovičić, Vladimir; Banjanac, Radomir; Knežević, David; 2023, ASR, 71, 4, 2006-2016.

Observation of Earth's magnetic field in search for earthquake precursors

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The changes in the magnetic field associated with the variations in the stress field were first observed by Stacey (1963) and Nagata (1969). Tectonomagnetism involves the variation of the magnetic field associated with the occurrence of the seismic events (Parkinson, 1983; Edwin et al., 1983). Reikitaki (1976) and Melon et al. (1998) studied the geomagnetic effect of earthquakes. A comparison of geomagnetic and seismic data shows the relation between these two quantities is quite evident. (Liu et al., 2006; ; Hayakawa et al., 2007; Ghamry et al., 2013).

In this study, the data are driven from the INTERMAGNET website. Some additional required data such as geomagnetic storm indices are extracted from Solar-Geophysical Data section of National Centers for Environmental Information and Space Weather Archive websites. According to Dobrovolski's relation $P=10^{0.43M}$ (Dobrovolski et al. 1979), it is expected that the precursory phenomena will be observed within a radius up to1000 km from the earthquake for a 7 magnitude earthquake. Among the various magnetic components, the X or horizontal components are usually more suitable for the proposed processing method.

The characteristic curve method is proposed here to reduce the effect of factors affecting the Earth's magnetic field at the magnetic stations' location. After identifying the station's geomagnetic nature, or in other words, the repetitive effect of daily variations observed at the station, the relevant effect is reduced from the data. These anomalies are then compared with the region's seismic activities by examining the anomalies which are more apparent after the above steps. Indeed, we separate the noise from the desired signal and finally the observed anomaly is more distinct. This way the usability of the data as an earthquake precursor is enhanced.

To display the geomagnetic data under discussion, one must first correct the values which are not correctly recorded, by replacing them with the previous or an average value. After selecting the appropriate time interval using the available data from each station, the repeated plot of the observed values over 24 hours interval shows the station's geomagnetic nature in question. This plot shows the characteristic curve.

Thus, each ground station has a characteristic curve for each magnetic field component, which estimates the expected values of these components within the desired time range. By subtracting these values from the geomagnetic record, it is possible to obtain purer anomalies and correlate them with the seismic activity. After getting the characteristic curve and subtracting it from the record to reduce the effect of the daily variations, the anomalies observed before the earthquakes are more intense. Based on the obtained results, anomalies in the magnetic field can be considered as earthquake predictions.

References

Dobrovolsky, I. P., Zubkov, S. I., and Miachkin, V. I., 1979. PAGEOPH (1979) 117: 1025. doi:10.1007/BF00876083.

Edwin, P. and Roberts, B., 1983. Wave propagation in a magnetic cylinder, Sol. Phys., 88, 179.

Ghamry, E., Yumoto, K. and Yayama, H., 2013. Effect of SC on frequency content of geomagnetic data using DWT application: SC automatic detection. Earth Planets Space, 65, 1007-1015.

Hayakawa, M., Httori, K., and Ohta, K., 2007. Monitoring of ULF (Ultra-Low-Frequency) Geomagnetic variations associated with earthquakes. Sensors, 7, 1108-1122.

INTERMAGNET (hosted by Natural Resources Canada, G. O. (2018, June 18). INTERMAGNET. Retrieved from http://intermagnet.org/index-eng.php.

Liu, J. Y, Chen, C. H, Chen, Y. I., and Yen, H. Y., 2006. Seismo-magnetic anomalies and $M \geq 5.0$ earthquakes observed in Taiwan during 1998-2001, Physics and Chemistry of the Earth, 2006, vol. 31, pp 215-222.

Meloni, A., Mele, G., and Palangio, P., 1995, Tectonomagnetic field observations in central Italy 1989-1995, Physics of Earth and Planetary Interiors, vol 105, pp 145-152.

Nagata, T., 1969. Tectonomagnetism. Z.A.G.A. Bull., 27: 12-43.

Parkinson, W. D., 1983. Introduction to geomagnetism. Edinburgh: Scottish Academic Press.

Rikitake, T., 1976. Earthquake Prediction, Elsevier Scientific Publishing Company

Solar-Geophysical Data, www.ngdc.noaa.gov, National Centers for Environmental Information (NCEI).

Space Weather Archive. (n.d.). Retrieved July 07, 2023, from https://www.spaceweatherlive.com/en/archive.

Stacey, F.D., Johnston M.J.S., 1963. Theory of the Piezomagnetic Effect in Titanomagnetite Bearing Rocks.

VLF propagation parameters modeling related to low intensity solar X-ray flares

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Solar X-ray flare (SF) events of low intensity are rarely investigated and their impacts on the subionospheric Very Low Frequency (VLF) propagation are not thoroughly described and annotated, primarily due to the prerequisite of quiet solar activity conditions and low-level X-ray emissions of background radiation. VLF propagation under events of such low-intensity SFs is inspected on VLF radio signal (3-30 kHz) recordings with path-oriented analysis conducted. Numerical modeling of VLF propagation parameters was carried out by the means of Long Wave Propagation Capability (LWPC) software package, based on VLF data recorded by Belgrade VLF stations (Serbia). Solar X-ray radiation data is obtained from Geostationary Operational Environmental Satellite (GOES) database. Main results are presented in this paper.

Key words: Solar flare, VLF perturbation, numerical modeling.

New perspectives in the analysis of Stark width regularities and systematic trends

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Regularites and systematic trends among the sample of Stark widths obtained by using modified semiempirical method from the STARK-B database were analysed. Two different approaches are independently used – multiple regression method combined with simple cluster analysis, and random forest (RF) machine learning algorithm. Predicted values of Stark widths calculated with estinates obtained from multiple regression method, and those values predicted by using RF algorithm, were compared with already known corresponding experimental Stark widths published elsewhere. Results of this analysis indicate that both of these methods can mostly predict new Stark width values within the acceptable range of accuracy.

SECTIONS (MINI PROJECTS)

M1 Modeling the Atmosphere: data&models,

M2 Big data in Astronomy and Earth Observations,

M3 A&M DATA and HPC,

M4 A&M DATA and standards,

M5 Radiative & Collisional Processes: databases,

M6 Spectra: stellar and laboratory plasmas.

A&M DATA

The fifth Meeting on Astrophysical Spectroscopy - A&M DATA - Astronomy & Earth Observations

Palić, Serbia, September 12 – 15, 2023

PROGRAMME

FIRST DAY. SEPTEMBER 12, 2023 (Tuesday)	
16:00-18:00	Arrival and Registration
18:00-18:15	Opening ceremony (Vladimir Srećković, Milan Dimitrijević)
18:15-18:30	**Milan S. Dimitrijević**, A brief history of the A&M DATA meetings
18:30-19:00	**Magdalena D. Christova, Milan S. Dimitrijević, Sylvie Sahal-Bréchot**, On the Stark broadening parameters of N VI spectral lines (Invited lecture)
19:00-20:00	Welcome Cocktail

SECOND DAY. SEPTEMBER 13, 2023 (Wednesday)	
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10:30-11:00	**Ilija B. Simonović, Danko V. Bošnjaković, Saša Dujko**, Simulations of positive and negative streamers in the AMReX environment (Invited lecture)
11:00-11:15	**Nikola Cvetanović, Saša S Ivković, Bratislav M. Obradović**, Spectroscopic method for nitrogen impurity estimation in helium atmospheric discharge
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12:00-12:30	**Duško Borka, Vesna Borka Jovanović, Salvatore Capozziello, Predrag Jovanović**, Constraining theories of gravity by velocity distribution of elliptical galaxies (Invited lecture)
12:30-12:45	**Milan S. Dimitrijević, Magdalena D. Christova**, On the Stark broadening parameters of Al IV spectral lines for stellar spectra analysis and synthesis (Invited lecture)
12:45-13:00	**Nenad M. Sakan, Z Simić, M Dechev, Vladimir A. Srećković**, The close vicinity ions as modifiers of the mean form of cut-off potential, simple approach
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	Željka D. Nikitović, Zoran M. Raspopović, Transport properties of H_2^+ ions in H_2 gas
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	Vladimir A. Srećković, Ljubinko M. Ignjatović, Milan Dimitrijević, Nikolai Bezuglov, Collisional processes involving Rydberg atoms: Rate coefficients
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10:30-11:00	**Jelena Marjanović, Dragana Marić, Zoran Lj. Petrović,** The role of breakdown data in atmospheric studies (Invited lecture)
11:00-11:15	**Filip Arnaut, Aleksandra Kolarski**, Alternative Evaluation Metrics for Machine Learning Model Selection in Ionospheric VLF Amplitude Data Exclusion
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M2 Big data in Astronomy and Earth Observations,
M3 A&M DATA and HPC,
M4 A&M DATA and standards,
M5 Radiative & Collisional Processes: databases,
M6 Spectra: stellar and laboratory plasmas.

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CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

52-355.3(048)
533.92:537.228.5(048)
539.184.27(048)
550.38(048)

MEETING on Astrophysical Spectroscopy - A&M DATA - Astronomy & Earth Observations (5 ; 2023 ; Palić)
Book of abstracts and contributed papers / V Meeting on Astrophysical Spectroscopy - A&M DATA - Astronomy & Earth Observations, September 12 - 15, 2023, Palić, Serbia ; edited by Vladimir A. Srećković ... [et al.] ; [organizers Institute of Physics Belgrade, Serbia]. - Belgrade : Institute of Physics, 2023 (Beograd : Skripta Internacional). - 91 str. : ilustr. ; 24 cm

Tiraž 50. - Bibliografija uz većinu apstrakata. - Registar.

ISBN 978-86-82441-61-8

а) Астрофизика – Апстракти б) Плазма – Спектрална анализа – Апстракти
в) Штарков ефекат – Апстракти г) Магнетизам земље – Апстракти

COBISS.SR-ID 123774729