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SCIENTIFIC RATIONALE

Spectroscopy is a powerful tool for the analysis of radiation from different plasmas in astronomy, laboratory, fusion research, atmospheric research and industry. Efficacy theoretical analysis, synthesis and modelling of stellar spectra as well as the spectra from other plasma sources, 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. Consequently, the development of databases with atomic data and astoinformatics is important for stellar spectroscopy.

The Conference is planned as an opportunity to consider 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 astronomical journals after the Conference.

Venue

Hotel "President", Palić, Serbia

CONTENTS

On the Stark broadening parameters of Fe XXV spectral lines for the investigation of neutron stars

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Broadening of spectral lines by collisions with charged particles or Stark broadening is significant for many important astrophysical quantities as for example modelling of stellar plasma, analysis and synthesis of spectral lines, it enters in the calculations of absorption coefficient, opacity, radiative transfer, abundance determination, acceleration of gravity etc. Stark broadening is the most important pressure broadening mechanism of spectral lines in the conditions of neutron star atmospheres and their envirionment.

However, when Stark broadening parameters of Fe XXV lines are needed for neutron star investigations, they are calculated very approximately, and without taking into account the magnetic field (see e.g. Paerels 1997, Madej 1989, Majczyna et al. 2005, Suleimanov et al. 2014). Usually very simple formula of Cowley (1971) or approximate formula from Griem (1974) book (cf. Chap. IV 6) are used.

In this contribution we calculated widths and shifts of Fe XXV spectral lines broadened by collisions with important charged constituents of neutron star atmospheres, electrons, protons and Fe XXVII ions. Calculations have been performed for a grid of temperatures and electron densities for plasma conditions of interest for neutron star atmospheres and their environments. Since such results are also of interest for Virtual Observatories we will prepare them additionaly 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).

References

Cowley, C. R., 1971, Observatory, 91, 139

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

Griem, H. R., 1974, Spectral line broadening by plasmas, Academic press

Madej, J., 1989, A&A, 209, 226.

Majczyna, A., Madej, J., Joss, P. C., Rózanska, A., 2005, A&A 430, 643.

Paerels, F., 1997, ApJ, 476, L47.

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

Suleimanov, V. F., Klochkov, D., Pavlov, G. G., Werner, K., 2014, ApJS, 210, 13

Recovering the fundamental plane of elliptical galaxies in the framework of nonlocal gravity model

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In this study we recovered fundamental plane (FP) of elliptical galaxies in the framework of nonlocal gravity without using dark matter hypothesis. Also, we investigated the relation between the parameters of the FP equation and the parameters of nonlocal gravity model. We compared theoretical predictions for circular velocity in nonlocal gravity with the corresponding values from a large sample of observed elliptical galaxies. From this sample, we use surface brightnesses, effective radius and velocity dispersion in our investigation. We show that nonlocal modified gravity can reproduce the stellar dynamics in elliptical galaxies and that it fits the observations very well.

Spectral index distribution of FR I and FR II radio lobes: Case study of 4C 11.71 and 4C 14.11

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The goal of this paper is to investigate the spectral index distribution of radio Active Galactic Nuclei (AGNs). We focused on the distribution of spectral indices over the lobes, as well as in their hotspots. For this purpose, we used the observations at several frequencies in radio domain, taken from the sky surveys. Particularly, we used Leahy's Atlas of radio-emitting Double Radiosources Associated with Galactic Nuclei (DRAGNs), Jodrell Bank Centre for Astrophysics in Manchester, and radio range surveys form Max-Planck-Institute for Radioastronomy in Bonn. We investigated an example of Fanaroff-Riley Class I (FR I) and an example of Fanaroff-Riley Class II (FR II) source. We found that the non-thermal (synchrotron) radiation dominates over the areas of the lobes.

Electron-metal atom vapor cross sections maintained within BEAM database

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Belgrade Electron-Atom/Molecule (BEAM) database [http://servo.aob.rs/emol] has been created in order to curate cross sections for electron interactions with atomic and molecular particles and with the aim to be a part (node) of other portals, as well as to fulfil a broader task of maintaining A/M data in a comprehensive way. It became an integral part of two portals: RADAM (Radiation Damage) database [1] and VAMDC (Virtual Atomic and Molecular data Centre) [2,3]. A significant number of entries within BEAM belongs to electron cross sections for metal vapor atoms. Elastic cross sections (Mg, Hg, Ag, Yt, Bi, Rb, Pb, Sb, Cd) and excitation cross sections (Mg, Hg, Ag, Yt, Na, Ca, Bi) have been compiled from the published refereed sources. Data entries within BEAMD follow IAEA classification scheme for processes [4] and use their standards for labelling of atomic states according Pyvalem as a Python package [5].

References

[1] S. Denifl, *et al.*, J. Phys. Conf. Ser. 438 012016 (2013).
[2] M. L. Dubernet, *et al.*, J. Phys. B 49, 074003 (2016).
[3] D. Albert, *et al.*, Atoms 8(4), 76 (2020).
[4] C. Hill, *et al.*, INDC(NDS) Publication 0812, (IAEA- International Atomic Energy Agency - Nuclear Data Section, Vienna International Centre, 2020) https://nds.iaea.org/publications/indc/indc-nds-0812/
[5] https://pypi.org/project/pyvalem/ (accessed on 25.11.2021).

Polarization in broad spectral lines of active galaxies: perspectives

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The polarization in the broad emission lines of active galactic nuclei (AGNs) is connected with light scatter on the dust which is in the form of dusty torus. This equatorial scattering in combination with Keplerina motion of the line emission gas can be used for the black hole mass measurements (see Afanasiev & Popovic 2015), but also for investigation of the geometry of broad line region (BLR). Here we give a short overview of the perspective to use the polarization in the broad emission lines for investigation of the central part of AGNs.

References

Afanasiev, V. L., & Popović, L. Č. (2015). Polarization in lines—a new method for measuring black hole masses in active galaxies. *The Astrophysical Journal Letters*, *800*(2), L35.

Excitation of silver atoms from the ground S state to the first excited P state by electron impact

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Silver is extensively employed in various scientific, technological and practical applications [1-3]. In our previous papers we reported results (differential DCSs and integrated ICSs cross sections) of combined experimental and theoretical study of excitation of the silver atom from the ground $4d^{10}5s^2$S state to the first combined resonant $4d^{10}5p\ ^2P_{1/2,3/2}$ state (fine-structure doublet with total angular momenta of J = ½ and 3/2 and energies of 3.664 and 3.778 eV, respectively) [4, 5]. Recently, we published results for electron impact excitation of the $4d^95s^2\ ^2D_{3/2}$ (4.304 eV) and $4d^{10}6s^2\ ^2S_{1/2}$ (5.276 eV) states [6]. Since McNamara *et al.* in their relativistic convergent close coupling (RCCC) computation [7] raised queries about the validity of our DCSs for resonant excitation, we have reanalyzed the earlier experimental DCS data. We have found that DCSs at 20 and 40 eV need to be renormalized due to incorrectly splicing our very forward-angular distributions onto our middle and backward-angular distributions. The new appropriate renormalization factor were applied and here we present new experimental DCSs results and the comparison with calculated relativistic distorted wave (RDW) and nonrelativistic atomic optical potential model data.

References

[1] V. A. Dzuba, S. O. Allehabi, V. V. Flambaum, J. Li and S. Schiller, Phys. Rev. A 103, 022822 (2021).

[2] T. Badr, M. D. Plimmer, P. Juncar, M. E. Himbert, Y. Louyer and D. J. E. Knight, Phys. Rev. A 74, 062509 (2006).

[3] D. Kasen, B. Metzger, J. Barnes, E. Quataert and E. Ramirez-Ruiz, Nature (London) 551, 80 (2017).

[4] S. D. Tošić, V. Pejčev, D. Šević, R.P. McEachran, A.D. Stauffer and B.P. Marinković, Nucl. Instrum. Methods B 279, 53 (2012).

[5] S. D. Tošić, V. Pejčev, D. Šević, R. P. McEachran, A. D. Stauffer and B. P. Marinković, Phys. Rev. A 91, 052703 (2015).

[6] , B. P. Marinković, S. D. Tošić, D. Šević, R. P. McEachran, F. Blanco, G. García and M. J. Brunger, Phys. Rev. A 104, 022808 (2021).

[7] K. McNamara, D. V. Fursa and I. Bray, J. Phys. B 51, 085203 (2018).

Integrated cross sections for electron impact excitation of atomic silver

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Here we present integrated (integral Q_I, momentum transfer Q_M, and viscosity Q_V) cross sections (ICSs) for electron-impact excitation of the $(4d^{10}5s)\ {}^2S_{1/2} \rightarrow (4d^{10}5p)\ {}^2P_{1/2,3/2}$, $(4d^{10}5s)\ {}^2S_{1/2} \rightarrow (4d^9 5s^2)\ {}^2D_{3/2}$ and $(4d^{10}5s)\ {}^2S_{1/2} \rightarrow (4d^{10}6s)\ {}^2S_{1/2}$ transitions in atomic silver at impact energies E_0 from 10 to 100 eV.

ICSs for all states were derived from the corresponding differential cross sections DCSs at each E_0. We extrapolated our experimental DCSs to 0^o (using the measured results at small scattering angles for resonant transition [1] and corresponding theory for other two states [2]) and 180^o (using the RDW calculations for the given energy [2,3]), performed an interpolation, and then undertake the appropriate integration. The new renormalized experimental DCSs for resonant excitation at 20eV and 40 eV were used (see abstract Excitation of silver atoms from the ground S state to the first excited P state by electron impact by S. D. Tošić *et al.*).

References

[1] S. D. Tošić, V. Pejčev, D. Šević, R.P. McEachran, A.D. Stauffer and B.P. Marinković, Nucl. Instrum. Methods B 279, 53 (2012).
[2] B. P. Marinković, S. D. Tošić, D. Šević, R. P. McEachran, F. Blanco, G. García and M. J. Brunger, Phys. Rev. A 104, 022808 (2021).
[3] S. D. Tošić, V. Pejčev, D. Šević, R. P. McEachran, A. D. Stauffer and B. P. Marinković, Phys. Rev. A 91, 052703 (2015).

Analysis of laser initiated electric discharge spark in atmosphere: clustering classification method

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Time resolved analysis of spectra of laser initiated electric discharge spark in atmosphere is presented here. Spectral images of optical emission of atmospheric plasma are obtained by a streak camera. Machine learning (ML) techniques are used more and more for analysis of LIBS data [1-6]. Here, large set of measured spectra are classified using Principal component analysis and clustering algorithms. For machine learning approach to data analysis we use Solo software package (Version 8.8, Eigenvector Research Inc, USA) [7].

References

[1] Bellou, E., Gyftokostas, N., Stefas D., Odhisea Gazeli O., Courisa S 2020. Laser-induced breakdown spectroscopy assisted by machine learning for olive oils classification: The effect of the experimental parameters. Spectrochimica Acta Part B: Atomic Spectroscopy, 163, 105476. https://doi.org/10.1016/j.sab.2019.105746

[2] Yang, Y., Hao, X., Zhang. L., Ren, L 2020. Application of Scikit and Keras Libraries for the Classification of Iron Ore Data Acquired by Laser-Induced Breakdown Spectroscopy (LIBS). Sensors, 20 (5), 1393. https://doi.org/10.3390/s20051393

[3] Diaz, D., Molina, A., Hahn, D.W 2019. Laser-Induced Breakdown Spectroscopy and Principal Component Analysis for the Classification of Spectra from Gold-Bearing Ores. Appl. Spectrosc. 74 (1), 42–54. https://doi.org/10.1177/0003702819881444

[4] Vrábel J., Képeš E., Duponchel L., Motto-Ros V., Fabre C., Connemann S., Schreckenberg F., Prasse P., Riebe D., Junjuri R., Gundawar M.K., Tan X., Pořízka P., Kaiser J., 2020. Classification of challenging Laser-Induced Breakdown Spectroscopy soil sample data - EMSLIBS contest. Spectrochimica Acta Part B 169, 105872. https://doi.org/10.1016/j.sab.2020.105872.

[5] Pořízka P., Klusa J., Képeš E., Prochazka D., Hahn D.W., Kaiser J., 2018. On the utilization of principal component analysis in laser-induced breakdown spectroscopy data analysis. Spectrochimica Acta Part B 148 (2018) 65–82. https://doi.org/10.1016/j.sab.2018.05.030

[6] Zhang D., Zhang H., Zhao Y., Chen Y., Ke C., Xu T., He Y., 2020. A brief review of new data analysis methods of laser induced breakdown spectroscopy: machine learning. Applied Spectroscopy Reviews. https://doi.org/10.1080/05704928.2020.1843175

[7] Wise, B.M., Gallagher, N.B., Bro, R., Shaver, J.M., Windig, W., Koch R.S., 2006. Chemometrics tutorial for PLS_Toolbox and Solo. ISBN: 0-9761184-1-6, Eigenvector Research, Inc. USA.

Data needed for low ionosphere modeling: new results and models

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Intense radiation can generate additional ionization in the Earth's atmosphere and affect its structure. These types of solar radiation and activity create sudden ionospheric disturbances (SIDs), affect electronic equipment on the ground along with signals from space, and potentially induce various natural disasters. Focus of this work is on the study of SIDs using very low frequency (VLF) radio signals in order to predict the impact of intense radiation on Earth and analyze ionosphere plasmas and its parameters. All data are recorded by VLF BEL stations [1] and the model computation is used to obtain the daytime atmosphere parameters induced by this extreme radiation [2]. We present an empirical model of the D-region plasma density and simple approximative formula for electron density.

References

[1] Šulić, D. M., Srećković, V. A., & Mihajlov, A. A. (2016). A study of VLF signals variations associated with the changes of ionization level in the D-region in consequence of solar conditions. *Advances in Space Research*, 57(4), 1029-1043.

[2] Srećković, V. A., Šulić, D. M., Ignjatović, L., & Vujčić, V. (2021). Low Ionosphere under Influence of Strong Solar Radiation: Diagnostics and Modeling. *Applied Sciences*, *11*(16), 7194.

Lower ionosphere under high-energy events: observations and model parameters

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Analysis of lower ionospheric response and electron density altitude profile variations in lower ionosphere induced by high-energy events during daytime and during nighttime was carried out. Sudden events induced changes in ionosphere and consequently electron density height profile. All data are recorded by BEL radio stations system and the model computation is used to obtain the atmospheric parameters induced by these perturbations. According to perturbed conditions, variation of estimated parameters, sharpness and reflection height differ for analyzed cases. The data and results are useful for Earth observation, telecommunication and other applications in modern society.

References

[1] Šulić, D. M., Srećković, V. A., & Mihajlov, A. A. (2016). A study of VLF signals variations associated with the changes of ionization level in the D-region in consequence of solar conditions. *Advances in Space Research*, 57(4), 1029-1043.
[2] Srećković, V. A., Šulić, D. M., Ignjatović, L., & Vujčić, V. (2021). Low Ionosphere under Influence of Strong Solar Radiation: Diagnostics and Modeling. *Applied Sciences*, *11*(16), 7194.

The collisional processes in geo-cosmical plasmas: A&M data needed for spectroscopy investigations

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In this paper, we investigate the chemi-ionization processes in atom-Rydberg atom collisions. The rate coefficients for chemi-ionization processes collisions are presented for a wide region of temperatures and principal quantum numbers. The data for the rate coefficients are very useful for the improvement of modelling and analysis of different layers of weakly ionized plasmas in atmospheres of various stars where these and other chemi-ionization processes could be important and could change the optical characteristics (see e.g. [1,2] and reference therein). Also, the results are of interest in spectroscopy of low temperature laboratory plasma.

References

[1] Mihajlov, A. A., Ignjatović, L. M., Srećković, V. A., & Dimitrijević, M. S. (2011). Chemi-ionization in solar photosphere: influence on the hydrogen atom excited states population. The Astrophysical Journal Supplement Series, 193(1), 2.

[2] Srećković, V. A., Mihajlov, A. A., Ignjatović, L. M., & Dimitrijević, M. S. (2014). Ion-atom radiative processes in the solar atmosphere: quiet Sun and sunspots. Advances in Space Research, 54(7), 1264-1271.

New insights from cross-correlation studies between solar activity indices and cosmic-ray fluxes during Forbush decreases

Nikola Veselinović, Mihailo Savić, Aleksandar Dragić, Dimitrije Maletić, Radomir Banjanac, Dejan Joković, David Knežević and Vladimir Udovičić

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Observed galactic cosmic rays intensity can be subjected to transient decrease, called Forbush decreases, which can be driven by solar activity and shockwaves in Heliosphere with solar origin, in terms of flares and coronal mass ejections (Miteva et al., 2018 [1]). By combining in-situ measurements, using space borne instruments, of solar energetic particles with ground-based observations we investigate the relationship between solar activity indices, as well as event-integrated spectra of solar energetic particles (Belov et al, 2021 [2]) with intensity measurements of cosmic rays during these strong transient decreases. We present cross-correlation studies (Veselinović et al, 2021 [3]) using data from the SOHO/ERNE measurements at 19 energy thresholds between 1.6 and 90 MeV/n, neutron monitors and solar observatories collected during strongest Forbush decreases over last two solar cycles.

References

[1] Miteva, R., Samwel, S.W. & Costa-Duarte, M.V. The *Wind*/EPACT Proton Event Catalog (1996 – 2016). *Sol Phys* **293,** 27 (2018). https://doi.org/10.1007/s11207-018-1241-5

[2] Belov A. *et al* 2021 *ApJ* **908** 5. https://doi.org/10.3847/1538-4357/abd724

[3] Veselinović, N., Savić, M., Dragić, A. *et al.* Correlation analysis of solar energetic particles and secondary cosmic ray flux. *Eur. Phys. J. D* **75,** 173 (2021). https://doi.org/10.1140/epjd/s10053-021-00172-x

Periodic variations in the influence of Ly radiation on the ionospheric D-region

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Solar hydrogen Lj alpha photons are the dominant source of ionization in the upper ionospheric D-region during quiet conditions. In this paper, we present a new procedure for modeling the parameters of a quiet D-region at different periods of the day, year, and solar cycle. This procedure requires monitoring of the D-region by two very low/low frequency (VLF/LF) signals emitted and recorded by relatively closely located transmitters and receivers. We provide analytical expressions for Wait's parameters over the part of Europe included within the location of the transmitted signals (Sardinia, Italy, for the ICV signal) and (Lower Saxony, Germany for the DHO signal) and the receiver in Belgrade, Serbia. The developed model enables the determination of the influence of the number of sunspots and days in the year on the midday ionospheric parameters. Their variations during a daytime period are calculated based on data related to the amplitude and phase of one VLF/LF signal recorded by one receiver.

VLF signal perturbations due to Solar flares monitored on close GCPs

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Incident X radiation from Sun, especially in soft X-ray spectral range (0.1-0.8 nm), in Earth's lower ionosphere leads to abrupt changes in local plasma environment, causing amplitude and phase delay perturbations of Very Low Frequency (VLF) radio signals transmitting within Earth-ionosphere waveguide, that come across transient electron density encasements. Amplitude and phase delay perturbations induced by moderate and relatively strong Solar flares occurred during daytime were monitored on VLF radio signals transmitted from Maine (44.63N, 67.28W) USA and Skelton (54.88N, 3.28W) UK, simultaneously received in Serbia and Hungary, by narrowband VLF receivers. For analysis of Solar X-ray radiation, data form GOES satellite mission were used. VLF data from second half of 23rd Solar cycle were analyzed for insight of possible path-related pattern structures in amplitude and phase delay of VLF data, as observed on recordings from spatially closely positioned signal traces along their Great Circle Paths (GCPs). Main results are presented in this paper.

D-region electron density enhancements due to Solar flares estimated from VLF recordings of close GCPs

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X-ray radiation from Sun in range 0.1-0.8 nm during Solar flare events induce remarkable transient enhancements in D-region electron density height profile, forcing Very Low Frequency (VLF) radio signals to undergo perturbations, causing amplitude and phase delay to distort from their regular unperturbed values and common behavior. This makes VLF radio signals (3-30 kHz) efficient and widely used tool for probing of lower ionosphere ionization within D-region (50-90 km). D-region electron density enhancements, induced by several X-ray Solar flares that occurred in second half of 23rd Solar cycle were estimated, based on narrowband recordings of GQD and NAA VLF signals transmitted from Maine (44.63N, 67.28W) USA and Skelton (54.88N, 3.28W) UK and simultaneously received in Serbia and Hungary. Solar X-ray data were obtained from GOES satellite database. According to observed flare induced amplitude and phase delay perturbations of analyzed VLF signals, D-region electron density height profiles were calculated throughout entire duration of analyzed flare events, by utilization of Long Wave Propagation Capability (LWPC) numeric routine code for modeling VLF subionospheric propagation. Main results are presented in this paper.

Excessive Doppler Broadening in spectra from Molecular Plasma

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The so called "excessive line broadening" is a well-established effect in the spectrum from low pressure hydrogen plasma [1]. This phenomenon is explained by the so-called Field Acceleration Model (FAM), see for instance [2]. According to FAM, three types of hydrogen ions, H^+, H_2^+ and H_3^+, are accelerated in the electric field and then undergo charge exchange reactions with H_2 molecule. Thereby, fast atoms are created, typically with kinetic energies of several hundreds of eV, with velocities in the electric field direction. Due to the Doppler shift in emission, the spectral lines are seen as very broad with a distinctive shape which depends on field direction. Experimental investigations were performed in a number of papers, see the references in [1] and [3]. Monte Carlo model was also applied for production and transport of fast H atoms in low pressure plasma [4]. The incidence of fast H atoms was shown to be important for astrophysical plasma e.g. [5]. Moreover, similar effect was also detected in nitrogen plasma, although less pronounced [6]. In this presentation, the excessive Doppler broadening is examined in a low-pressure discharge for three lines of Balmer series. The fast atoms reached velocities up to 500 km/s. In addition, the same experiment is conducted in nitrogen and oxygen, and excessive broadening was detected using high-resolution spectrometer.

References

[1] A.V. Phelps, Plasma Sources Sci. Technol. 20, 043001 (2011)
[2] A.V. Phelps, Phys. Rev. E 79, 066401 (2009)
[3] B.M. Obradović et al., Plasma Sources Sci. Technol. 23, 015021 (2014)
[4] N. Cvetanović, B.M. Obradović, M.M. Kuraica, J. Appl. Phys. 105, 043306 (2009)
[5] D. L. Huestis et. al., Space Sci. Rev. 139, 63 (2008)
[6] Z. Wang, S.A. Cohen, D.N. Ruzic, and M. J. Goeckner Phys. Rev. E 61, 1904 (2000)

Curve fitting method of Stark width determination – example of H I line in Sirius B spectrum

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Astrophysical application of Stark broadening theory were intensively developed in the last hundred years. For example, Verweij (1936) among the others pointed out the importance of Stark broadening influence on spectral line shape even in the core of Balmer lines measured in the spectrum of the objects with log g > 5, e.g. white dwarfs. Since then, many of scientific investigation has been done to prove significance of taking Stark width into consideration during spectral analysis of white dwarfs, even if the other elements have been investigated instead of hydrogen, where Stark broadening has affected more on wings than on the core of the spectral line. We propose here simple curve fitting method for experimental determination of Stark width in the example of Ly α line in the spectrum of Sirius B, which is one of the earliest identified white dwarfs. After comparison of our synthefic line with measured one, model of the white dwarf atmosphere is used for determination of atmospheric depth which, according to our assumptions, considered spectral line comes from.

Elementary physical processes, transport and scattering, of electrons in planetary atmospheric discharges

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Lightning is one of the most spectacular natural phenomena and definitely one of the most dramatic. In the chain of processes leading to lightning, the electron scattering from the gas molecules, transport and thermalization of the electrons, are fundamental processes, followed by large-scale charge separation which results in the build-up of a strong electric field. Lightning is not just associated with our planet. It has been observed on the various planets of the solar system. While the appearance of lightning on Venus and eventually in dust storms on Mars are still open issues, we have clear evidences of lightning on Jupiter, Saturn, Uranus and Neptune [1].

It is well-documented, that lightning discharges produce electromagnetic pulses (EMP), due to the rapid current pulse, as well as a quasi-electrostatic (QE) field due to the removal of charge from the thundercloud. When the QE field exceeds the breakdown threshold in the mesosphere of our planet, the sprite discharges can be initiated, while the EMP field similarly leads to heating, ionization and optical emissions often referred to as elves [2].

In this work, we study the properties of electron transport in gaseous mixtures that mirror planetary atmospheres. Calculations have been performed over a range of the applied electric fields using a numerical solution of the Boltzmann equation [3]. The following influences of specific physical processes on electron kinetics are identified: (i) for Earth's atmosphere the effects of 3-body attachment are studied, (ii) for Venusian atmosphere the effects of the gas temperature are examined, and (iii) for gas giants, the influence of planetary magnetic field is investigated. Calculations of electron transport properties have also been performed in radio-frequency electric and magnetic fields. The calculated transport coefficients are then used as input in fluid models of various orders for streamer discharges [4]. Values of streamer velocity, ionization level behind the front and average electronic energies are calculated for various gas mixtures relevant to planetary atmospheres.

References

[1] C. Helling, R.G.Harrison, F. Honary, D.A. Diver, K. Aplin, I.D. Dixon, U. Ebert, S. Inutsuka, F. J. Gordillo-Vazquez and S. Littlefair, Surv. Geophys. **37** (2016) 705–756

[2] U. Ebert, S. Nijdam, C. Li, A. Luque, T. Briels and E. van Veldhuizen, J. Geophys. Res. **115** (2010) A00E43

[3] S. Dujko, R.D. White, Z.Lj. Petrović and R.E. Robson, Phys. Rev. E **81** (2010) 046403

[4] S. Dujko, A.H. Markosyan, R.D. White and U. Ebert, J. Phys. D: Appl. Phys. **46** (2013) 475202

X-ray Solar flare signatures on two VLF signals through seasons

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X-ray radiation from Solar flare bursts highly affects subionospheric propagation of Very Low Frequency (VLF) (3-30 kHz) radio signals, transmitting in altitude range of lower ionospheric D-region (50-90 km). Caused deviations in signals' amplitude and phase delay from their regular values can be used for reconstruction of ionospheric plasma features. Amplitude and phase delay of VLF radio signals emitted from USA on frequency 24 kHz and UK on 22.1 kHz, and received in Belgrade (Serbia) by The Absolute Phase and Amplitude Logger (AbsPAL) recording system at the Institute of Physic (44.85N, 20.38W), were surveyed for signatures of isolated Solar flare events of moderate intensity (C and M class) through different seasons during the second half of the 23rd Solar cycle. Solar flux data were taken from GOES satellite database. Numerical simulations of related perturbations forced by inspected Solar flare events were performed using Long Wave Propagation Capability (LWPC) software. Main results are presented in this paper.

Effects of moderate X-ray Solar flares observed on VLF signals with relatively short GCPs

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Abstract

Solar electromagnetic energy of wavelength range 0.1-0.8 nm, emitted during occurrence of Solar flare events and often called soft X-ray radiation, penetrates deep into the Earth's atmosphere, where causes abrupt and intense changes of ionized medium within altitude range 50-90 km that corresponds to lower Ionosphere. D-region is used by Very Low Frequency (VLF) radio signals for their transmission, so their propagation parameters are highly sensitive to related sudden environmental plasma changes due to incident Solar flare energy. Effects of Solar flare events of moderate intensity of C and M class were analyzed on VLF data recorded by narrowband recording system located in Belgrade, Serbia, at the Institute of Physic (44.85N, 20.38W). Time span for analysis encompasses VLF data registered during the second half of the 23rd Solar cycle, mainly in period from 2004 to 2008. Solar flare signature analysis had focus on VLF signals of relatively short paths and included GQD/22.1 kHz, DHO/23.4 kHz, HWU/18.3 kHz and ICV/20.27 kHz signals, emitted from European military transmitters located in UK, Germany, France and Italy, respectively, and registered in Belgrade during inspected time period. Time evolution of flare induced series of perturbations, with accompanying related propagation parameters' deviations from their regulars, was inspected in detail. For lower Ionospheric plasma environment modeling, Long Wave Propagation Capability (LWPC) software, both for regular and perturbed ionization states, was applied. Main results are presented in this paper.

Key words: Solar flare, VLF signal, lower Ionosphere, perturbation, density change, D-region.

Introduction

Sudden outbursts of electromagnetic energy emitted from Sun within wavelength range 0.1-0.8 nm (soft X-ray radiation) abruptly change properties of ionized medium originating in sunlit Earth's atmosphere, at Ionospheric D-region altitudes 50-90 km [1]. SubIonospheric propagation of Very Low Frequency (VLF) radio signals (3-30 kHz) is highly sensitive to sudden environmental plasma changes in lower Ionosphere induced by incident Solar flare energy. VLF signals globally transmitting with stable propagation (e.g. [2-4]) are commonly used as the tool for remote sensing of the lower Ionosphere, for vast range of forcing agents of extraterrestrial and terrestrial origin. Variety of different aspects is covered in numerous manuscripts (review of relatively recent results is summarized in e.g. [5] and references therein). In this paper, VLF technique is used for analysis of effects of X-ray Solar flares of moderate intensity on the lower Ionosphere, based on VLF signal propagation.

VLF data used in this research were taken from database of VLF radio signals of The Absolute Phase and Amplitude Logger (AbsPAL) narrowband receiving system, operating at the Institute of Physics in Belgrade (44.85N, 20.38W), Serbia. Research focus was VLF signals of relatively short Great Circle Paths (GCPs) under influence of Solar flare radiation of moderate intensity in soft X-range. Solar flare events, from the second half of 23rd Solar cycle and their signatures on VLF signals were examined, with aim to determine lower Ionospheric plasma characteristics affected by C and M class Solar flares, as deduced from VLF data registered in Belgrade.

For modeling purposes of lower Ionospheric conditions, before, under perturbations induced by Solar flare events and after that influence, procedure for simulation of subIonospheric propagation of VLF signals incorporated within Long Wave Propagation Capability (LWPC) [6] software was used. The outline of LWPC software is propagation of VLF signals in stratified medium implying exponential conductivity increase with height within incorporated Ionospheric model, with propagation of VLF signals described by hop wave theory (e.g. [7, 8]) and Earth-Ionosphere waveguide with its upper boundary defined by the lower edge of the Ionosphere and its lower boundary defined by Earth′s surface based upon real globally measured values of electro-conductivity. Propagation model [9] is defined by the electron density Ne (m^{-3}) within the waveguide at the altitude z (km), as described by parameter pairs denoted reflecting edge *sharpness* β (km^{-1}) of the lower Ionospheric boundary and *reflecting height* H′ (km). Wait′s theory defines Ne (m^{-3}) through relation designed for daytime Ionospheric conditions as:

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

As the output, program gives calculated amplitude and phase delay based on propagation simulation of defined VLF signal along chosen path, taking into account the whole range of parameters as background data (such as signal frequency, bearing angle, receiver and transmitter locations, observed date and time, solar zenith angle, geomagnetic dip, electro-conductivity of lower waveguide boundary etc). Proposed model within LWPC software package, in case of daytime unperturbed regular Ionospheric conditions, takes (β, H′) parameter pair defined as (0.3, 74), but for modeling purposes it is necessary manually to input into the software wanted parameter pairs (β, H') in order to model just segment of the path or the whole path entirely, depending of conducted calculations′ complexity.

Analysis and results

Belgrade AbsPAL station works in fully operational mode since 2004, although there are also some registrations during the last trimester of 2003. During inspected period, several VLF signals were registered: NAA/24.0 kHz emitted from USA, GQD/22.1 kHz from UK, NWC/19.8 kHz from Australia, DHO/23.4 kHz from Germany, ICV/20.27 kHz from Italy, HWU/18.3 kHz from France and also from some other transmitters, but the latter in short time segments and usually not with good data quality. In general, long GCP NAA/24.0 kHz and NWC/19.8 kHz signals (about 6.5 Mm and near 12 Mm, respectively), and short GCP GQD/22.1 kHz signal (near 2 Mm), were registered continually and usually with good quality data. Among other short GCP signals, there were often alterations, but mostly were registered HWU/18.3 kHz (near 1.5 Mm), DHO/23.4 kHz signals (1.3 Mm) and ICV/20.27 kHz (near 1 Mm). VLF signals registered by Belgrade AbsPAL receiver during period 2004-2009 are given in Fig. 1. Characteristics of VLF transmitters

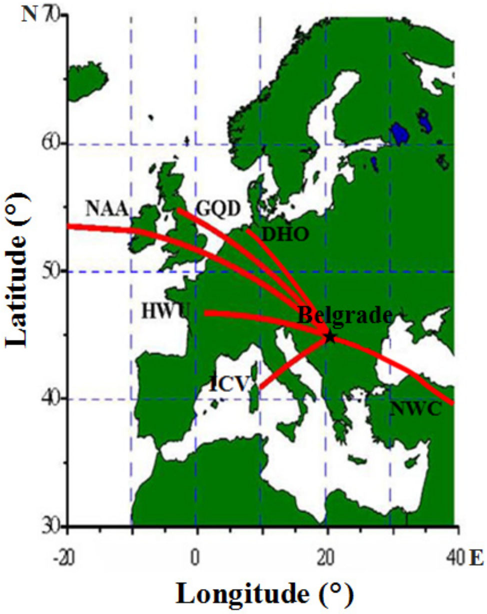


Fig. 1. VLF signals (in red) registered in Belgrade (star) by AbsPAL receiver in period 2004-2009

Table 1. VLF transmitters (T_x) and VLF signals registered in Belgrade during analyzed period

VLF signal (kHz)	T_x location	T_x power (kW)	GCP (km)
NAA/24.0	Maine, USA (44.63N; 67.28W)	1000	6547
GQD/22.1	Skelton, UK (54.72N; 2.88W)	300	1982
NWC/19.8	H. E. Holt, Australia (27.2S; 114.98E)	1000	11975
DHO/23.4	Rhauderfehn, Germany (53.08N; 7.62E)	800	1301
ICV/20.27	Isola di Tavolara, Italy (NATO) (40.92N; 9.73E)	20	970
HWU/18.3	Rosnay, France (NATO) (46.71N; 1.24E	400	1493

and Great Circle Path (GCP) length of VLF signals registered in Belgrade during the analyzed period are given in Table 1.

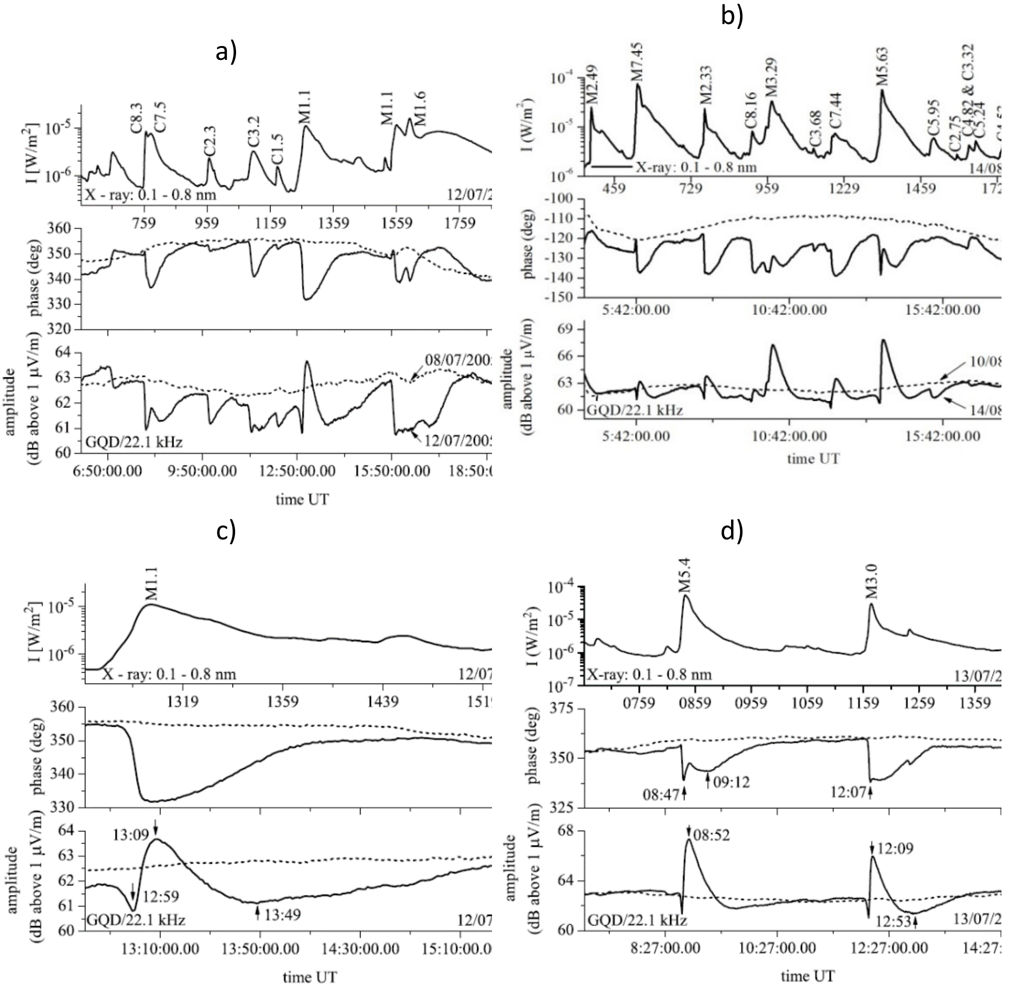
Analysis was conducted for short path VLF signals, with GQD signal depicted in detail. Examples of monitored Solar flare signatures on GQD signal, during two very active days and some representative examples of recorded VLF perturbations, induced by Solar flare events of moderate intensity within period of interest, are given in Fig. 2. Detailed analysis of GQD signal amplitude and phase delay perturbations induced by selected C and M class flare events, from period December 2005 – July 2006 (Table 2 and Fig. 3) was carried out, with corresponding propagation parameters′ modeling procedure conducted throughout the entire time evolution of inducing X-ray Solar irradiances, implemented by utilization of Long Wave Propagation Capability (LWPC) numeric routine code for modeling VLF subIonospheric propagation. GQD signal amplitude and phase delay perturbation, induced by shown flare events, differ in patterns between one another, due to diurnal and seasonal propagation factors and also due to different time evolution of selected flares, but in general have oscillatory character, which is characteristic feature for this signal as registered in Belgrade [10, 11]. Sluggishness of the Ionosphere [12, 13] in analyzed cases is of absolute amount up to 2 min, for main signal extremum, both in case of amplitude (D_A) and phase delay (D_P) [12, 14].

Table 2. Flare events of moderate intensity which effects were inspected on analyzed GQD/22.1 kHz signal

date (dd-mm-yy)	Ix_{max} time (UT)	flare class	Ix_{max} (Wm^{-2})	D_A (min)	D_P (min)	quiet day (dd-mm-yy)	preflare state in waveguide
07-04-06	08:03	C9.7	$9.74 \cdot 10^{-6}$	1	2	08-04-06	regular
06-07-06	08:36	M2.5	$2.51 \cdot 10^{-5}$	1	-2	05-07-06	regular
06-12-06	12:58	C4.8	$4.82 \cdot 10^{-6}$	1	1	08-12-06	perturbed
07-09-05	12:44	C9.6	$9.62 \cdot 10^{-6}$	2	0	08-09-05	perturbed

Regular (A_{reg}, P_{reg}) and perturbed (A_{flare}, P_{flare}) VLF data were directly obtained from VLF recordings, by reading these values from registered GQD signals in Belgrade. Difference between measured perturbed and regular values (ΔA and ΔP) was calculated by simple subtraction of regular from perturbed values, i.e. as $\Delta A = A_{flare} - A_{reg}$ and $\Delta P = P_{flare} - P_{reg}$). All these data were used as an input data, for conducted modeling procedure by means of LWPC program, when defining input parameter pairs (β, H') in REXP subroutine. Modeling of lower Ionospheric properties under influence of selected moderate flare events was designed in that manner, primarily to get modeled pair of values (ΔA_m and ΔP_m), but also modeled values of amplitude (A_m, both regular and perturbed) and phase delay (P_m, both regular and perturbed), as close as possible to real measured data red from registered signals. In this way, simulated signal propagation conditions, both in unperturbed state and under influence of flare, can be considered to appropriately depict real propagation in Earth-ionsphere waveguide. Modeling procedure itself consists of numerous trial and error iterations applied until desired accuracy of output results (ΔA_m, ΔP_m, A_m and P_m) is achieved (here, within 10-20%). Based on the modeled parameters (β, H') obtained from simulations as final best fitting pair, electron density height profile is calculated using relation (1).

On one hand, modeling either can be performed for some chosen characteristic moments during the influence of Solar X-radiation, depending on signal′s perturbation pattern features and complexity, or for entire time evolution of Solar flare event and on the other hand, modeled values of electron density within altitude range corresponding to sunlit D-region either can be calculated for some chosen heights, or throughout the entire altitude range. In case of VLF signals of short GCPs, when entirely sunlit, propagation within entire waveguide can be described with single pair of (β, H′), depicting average conditions along signal trace during modeling. In this paper, modeling was performed for entire time interval during the influence of chosen flare events onto the GQD signal and for the entire altitude range of heights from 50 to 90 km. For the sake of visibility, only characteristic moments (marked with arrows in Fig. 3) and corresponding electron density variations (Fig. 4) are presented here, with some chosen parameters listed in Table 3 (e.g. Ne (60 and 85 km) (m^{-3})) .



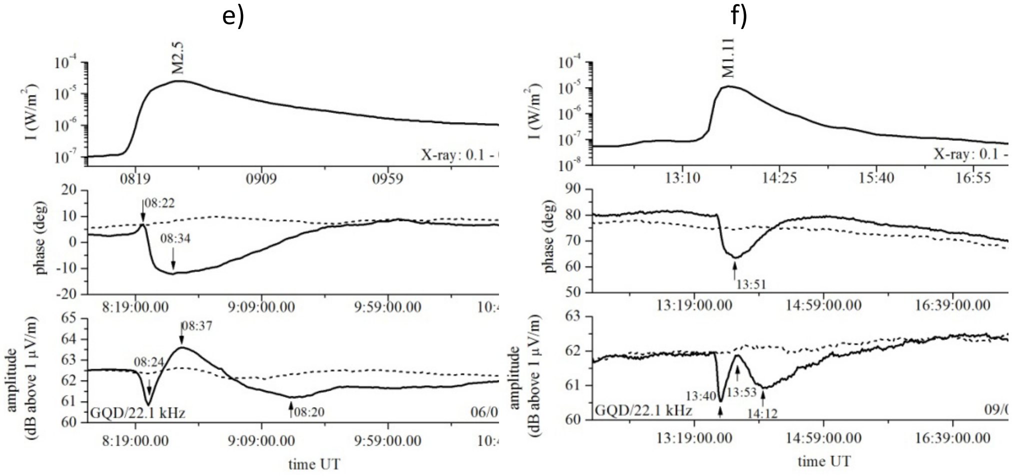
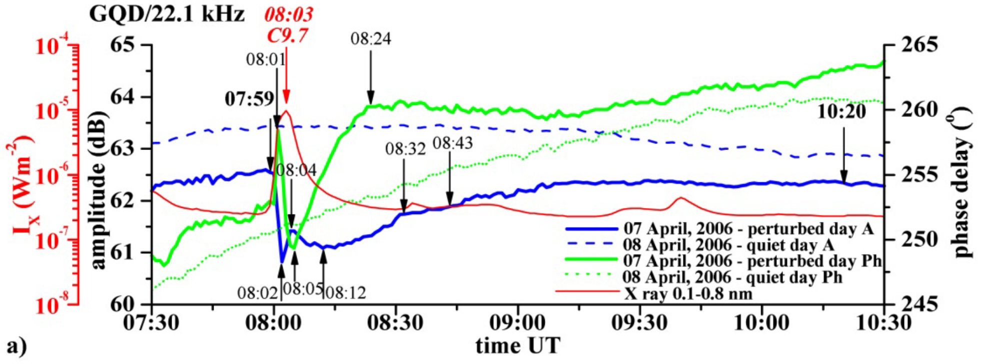


Fig. 2. GQD signal amplitude and phase delay perturbations (lower and middle panels – solid lines) induced by Solar flare events of moderate intensity (X-ray irradiance - upper panels): a) during very active periods on 12th July, 2005 (quiet day 08th July, 2005 – dashed lines) and b) 14th August, 2004 (quiet day 10th August, 2004), and by c) M1.1 Solar flare occurred at 13:06UT on 12th July, 2005 (quiet day 08th July, 2005), d) M5.4 and M3.0 Solar flares occurred at 08:48UT and 12:08UT respectively on 13th July, 2004 (quiet day 08th July, 2005), e) M2.5 Solar flare occurred at 08:36UT on 06th July, 2006 on the left (quiet day 05th July, 2006) and f) M1.11 Solar flare occurred at 13:48Ut on 09th June, 2007 on the right (quiet day 10th June, 2007); signal extrema are indicated by arrows and time UT.



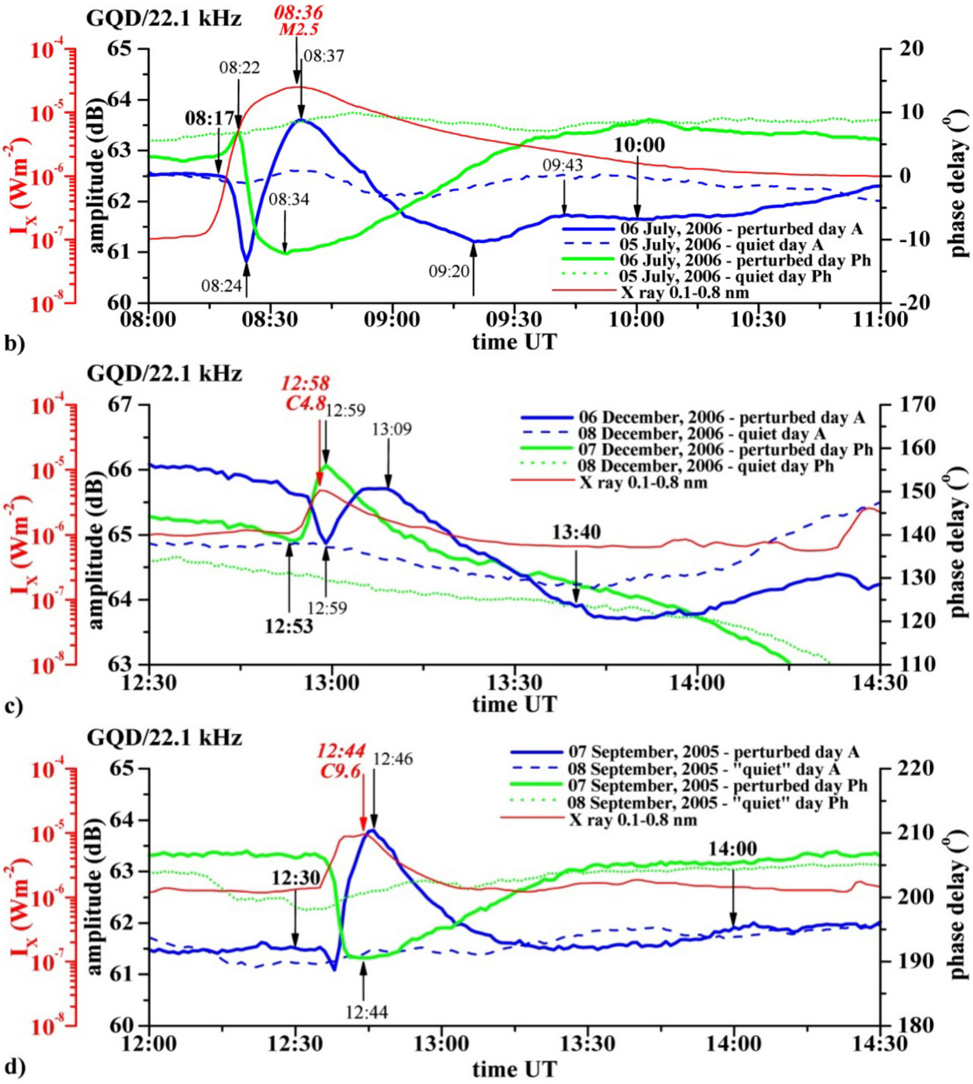


Fig. 3. Variation of GQD signal forced by Solar flares of moderate intensity (red thin solid lines) from 2005-2006: a) C9.7 (08:03UT) flare event occurred on 07th April, 2006, b) M2.5 (08:36UT) on 06th July, 2006, c) C4.8 (12:58UT) on 06th December, 2006 and d) C9.6 (12:44UT) on 07th September, 2005; perturbed signal amplitude and phase delay – blue and green thick solid lines, respectively; regular signal amplitude and phase delay – blue dashed and green dotted lines; signal extrema indicated by black arrows and time UT, while flare event in red.

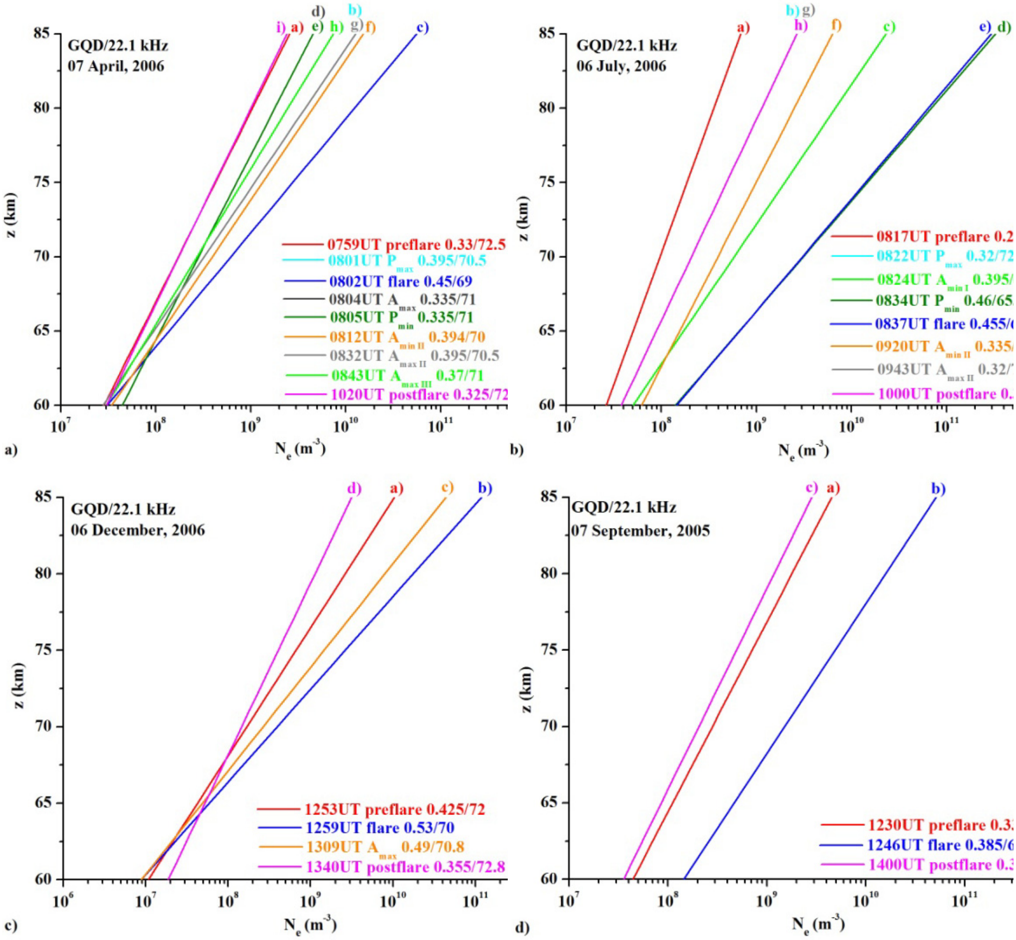


Fig. 4. Electron density height profile variations within D-region, corresponding to induced Ionosation changes under considered Solar flare events of moderate intensity: a) C9.7 (08:03UT) flare event occurred on 07th April, 2006, b) M2.5 (08:36UT) on 06th July, 2006, c) C4.8 (12:58UT) on 06th December, 2006 and d) C9.6 (12:44UT) on 07th September, 2005; preflare Ionospheric state is indicated in red, state that corresponds to Ix_{max} irradiance is given in blue and posltflare state in pink; for striking signal extrema indicated by black arrows accompanied signal state and parameter pairs (β, H′) are shown.

Electron densities estimated by similar modeling procedure at height 74 km (Table 3), although conducted for several moments during time evolution of analyzed flare events is presented in [15] with electron density height profiles modeled for preflare, flare and postflare GQD signal states. Also, some additional information on Ne (m^{-3}) at D-region boundaries at altitudes 50 and 90 km for preflare, flare and postflare GQD signal states, with some Ionospheric plasma behavior comparisons in case of long NAA path, as registered by Belgrade AbsPAL VLF receiver during considered flare events, can be found in [16]. In present research, modeling procedure was conducted for entire time evolution of considered Solar flare events, with electron density height profile variations estimated within entire altitude range that corresponds to lower Ionosphere D-region (50-90 km).

Table 3. Parameters characterizing GQD/22.1 kHz signal propagation conditions under influence of considered X-ray Solar flare events of moderate intensity

flare date (dd-mm-yy) timeUT	time (UT)	signal state	ΔA (dB)	ΔP (o)	β (km^{-1})	H′ (km)	Ne (m^{-3})		
							74 km [15]	60 km	85 km
07-04-06 08:03UT C9.7	**07:59**	preflare	-0.89	2.52	0.33	72.5	$3.54\cdot10^{8}$	$2.85\cdot10^{7}$	$2.57\cdot10^{9}$
	08:01	P_{max}	-1.72	7.68	0.395	70.5	$8.61\cdot10^{8}$	$2.79\cdot10^{7}$	$1.27\cdot10^{10}$
	08:02	flare	-2.62	4.93	0.45	69	$2.05\cdot10^{9}$	$3.07\cdot10^{7}$	$5.56\cdot10^{10}$
	08:04	A_{max1}	-1.98	-1.69	0.335	71	$5.90\cdot10^{8}$	$4.43\cdot10^{7}$	$4.52\cdot10^{9}$
	08:05	P_{min}	-1.99	-1.78	0.335	71	$5.90\cdot10^{8}$	$4.43\cdot10^{7}$	$4.52\cdot10^{9}$
	08:12	A_{min2}	-2.34	3.09	0.394	70	$1.04\cdot10^{9}$	$3.43\cdot10^{7}$	$1.53\cdot10^{10}$
	08:32	A_{max2}	-1.71	6.28	0.395	70.5	$8.61\cdot10^{8}$	$2.79\cdot10^{7}$	$1.27\cdot10^{10}$
	08:43	A_{min3}	-1.55	4.48	0.37	71	$6.56\cdot10^{8}$	$3.01\cdot10^{7}$	$7.37\cdot10^{9}$
	10:20	postflare	-0.53	2.31	0.325	72.5	$3.52\cdot10^{8}$	$3.04\cdot10^{7}$	$2.41\cdot10^{9}$
06-07-06 08:36UT M2.5	**08:17**	preflare	0.04	-3.44	0.28	75	$1.63\cdot10^{8}$	$2.65\cdot10^{7}$	$6.82\cdot10^{8}$
	08:22	P_{max}	-0.72	0.11	0.32	72	$4.10\cdot10^{8}$	$3.79\cdot10^{7}$	$2.66\cdot10^{9}$
	08:24	A_{min1}	-1.54	-6.46	0.395	69	$1.56\cdot10^{9}$	$5.04\cdot10^{7}$	$2.31\cdot10^{10}$
	08:34	P_{min}	0.76	-20.34	0.46	65.5	$1.08\cdot10^{10}$	$1.41\cdot10^{8}$	$3.26\cdot10^{11}$
	08:37	flare	1.0	-20.25	0.455	65.5	$1.03\cdot10^{10}$	$1.44\cdot10^{8}$	$2.96\cdot10^{11}$
	09:20	A_{min2}	-1.11	-6.54	0.335	70	$8.25\cdot10^{8}$	$6.19\cdot10^{7}$	$6.32\cdot10^{9}$
	09:43	A_{max2}	-0.79	-0.99	0.32	72	$4.10\cdot10^{8}$	$3.79\cdot10^{7}$	$2.66\cdot10^{9}$
	10:00	postflare	-0.79	-0.44	0.32	72	$4.10\cdot10^{8}$	$3.79\cdot10^{7}$	$2.66\cdot10^{9}$
06-12-06 12:58UT C4.8	**12:53**	preflare	0.8	7.44	0.425	72	$5.06\cdot10^{8}$	$1.08\cdot10^{7}$	$1.04\cdot10^{10}$
	12:59	flare	0.06	26.71	0.53	70	$1.80\cdot10^{9}$	$8.81\cdot10^{6}$	$1.18\cdot10^{11}$
	13:09	A_{max}	1.09	15.41	0.49	70.8	$1.04\cdot10^{9}$	$8.88\cdot10^{6}$	$4.36\cdot10^{10}$
	13:40	postflare	-0.33	5.51	0.355	72.8	$3.31\cdot10^{8}$	$1.88\cdot10^{7}$	$3.16\cdot10^{9}$
07-09-05 12:44UT C9.6	**12:30**	preflare	0.29	2.09	0.355	71	$5.90\cdot10^{8}$	$4.43\cdot10^{7}$	$4.52\cdot10^{9}$
	12:46	flare	2.32	-13.33	0.385	66.5	$3.88\cdot10^{9}$	$1.44\cdot10^{8}$	$5.14\cdot10^{10}$
	14:00	postflare	0.19	1.36	0.325	72	$4.14\cdot10^{8}$	$3.57\cdot10^{7}$	$2.84\cdot10^{9}$

Discussion and conclusions

Propagation model based on Wait′s parameters and LWPC calculations can be used for VLF signal subionospheric propagation simulations both for unperturbed conditions [14, 17-19] and perturbed conditions due to Solar flare events. Complexity of D-region response to incident X-ray radiation from Sun and variation of Solar flare events′ characteristics themselves, is the reason that issue has been treated from many and diverse aspects primarily regarding flare peak irradiance in perturbed state (e.g. [20, 21]), relaxation period (e.g. [22, 23]), different flare classes (e.g. [10, 11, 14-16, 24-29]) and on the other hand mid- (e.g. [30-38]), low-latitude ionopsphere (e.g. [39-41]) etc. In this paper, utilization of LWPC code routine was applied to selected VLF data from second half of the 23rd Solar cycle, mainly from 2004 to 2008, with goal to inspect Solar flare signatures on VLF signals of relatively short paths, emitted from European military transmitters towards Belgrade AbsPAL receiver station.

In case of GQD/21.1 kHz signal, series of perturbations forced by Solar flare events were thoroughly reviewed and inspected in detail throughout entire time evolution of flare influence. Few chosen events are presented in this paper, with corresponding propagation parameters′ variations related to soft X-ray Solar irradiance. The Earth-ionosphere waveguide was modeled during the entire duration of analyzed flare events′ influence on the lower Ionosphere. Results obtained from LWPC software through conducted modeling procedure are in good agreement with real VLF signal measurements. It can be concluded that modeled averaged waveguide states realistically depict real states of the ionospheric plasma environments held in certain time periods along GQD signal path, as perturbed by these flare events, but also in unperturbed preflare and recovered postflare states.

Determining of ionospheric parameters by different methods introduces errors of about one order of magnitude (factor 10) and also, deviations in determining electron concentrations using different models vary for different altitudes. Comparison of results presented here, with published results of other researchers from Belgrade VLF group in first place, and with some other mid-latitude case studies, shows that in case of perturbed flare state related to Ix_{max} electron density ratios are within one order of magnitude compared to values given in [11, 14], while in case of unperturbed flare state electron density ratios are smaller than those given [23]. Electron densities at 74 km altitude are realistic and in line with results given in [14, 21, 34, 35, 43], and electron density height profiles are realistic. Determining ionospheric parameters and electron density height distribution by sophisticated numerical techniques can give more precise results (e.g. [40, 33, 14; 44, 45]), nevertheless, applied Wait theory and LWPC software provide satisfactory modeling results for the purposes of qualitative analysis such as conducted in this paper.

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References

1. Whitten, R.C., Poppoff, I.G. (1965) Physics of the Lower Ionosphere. Englewood Cliffs, N.J. Prentice-Hall.
2. Budden, K.G. (1988) The propagation of radio waves. Cambridge University Press, UK.
3. Thomson, N.R. (1993) Experimental daytime VLF ionospheric parameters. *J. Atmos. Sol.-Terr. Phys.* 55 (2), 173–184.
4. McRae, W.M., Thomson, N.R. (2000) VLF phase and amplitude: daytime ionospheric parameters. *J. Atmos. Sol.-Terr. Phys.* 62, 609–618.
5. Silber, I., Price, C. (2017) On the Use of VLF Narrowband Measurements to Study the Lower Ionosphere and the Mesosphere–Lower Thermosphere. *Surveys in Geophysics*. 38(2), 407–441.
6. Ferguson, A.J. (1998) Computer Programs for Assessment of Long-Wavelength Radio Communications, Version 2.0. Technical document 3030. Space and Naval Warfare Systems Center, San Diego CA 92152-5001.
7. Budden, K.G. (1961) The Waveguide Mode Theory of Wave Propagation. Logos Press, London, UK.
8. Wait, R.J. (1970) Electromagnetic Waves in Stratified Media. Pergamon Press, Oxford, UK.
9. Wait, R.J., Spies, K. P. (1964) Characteristics of the Earth-Ionosphere waveguide for VLF radio waves. NBS Technical Note 300, USA.
10. Grubor, D., Šulić, D., Žigman, V. (2005) Influence of Solar x-ray flares on the Earth-ionosphere waveguide. *Serb. Astron. J.* No. 171, 29 – 35.
11. Grubor, D.P., Šulić, D.M., Žigman, V. (2008) Classification of X-ray solar flares regarding their effects on the lower ionosphere electron density profile. *Ann. Geophys.* 26, 1731–1740.
12. Mitra, A.P. (1974) Ionospheric effects of solar flares. Astrophysics and Space Science Library, vol. 46, D. Reidel publishing Company, Boston.
13. Appleton, E.V. (1953) A note on sluggishness of ionosphere. *J. Atmos. Sol.-Terr. Phys.* 3, 282–284.
14. Žigman, V., Grubor, D., Šulić, D. (2007) D-region electron density evaluated from VLF amplitude time delay during X-ray solar flares. *J. Atmos. Sol.-Terr. Phys.* 69, 775–792.
15. Kolarski, A., Grubor, D. (2014) Sensing the Earth's Low Ionosphere during Solar Flares using VLF Signals and GOES Solar X-ray Data. *Adv. Space Res.* 53, 11, pp. 1595 – 1602.

16. Kolarski, A., Grubor, D. (2015) Comparative Analysis of VLF Signal Variation along Trajectory Induced by X-ray Solar Flares. *J. Astrophys. Astr.* Vol. 36, No. 4, pp. 565–579.
17. Thomson, N.R. (1993) Experimental daytime VLF ionospheric parameters. *J. Atmos. Sol.-Terr. Phys.* 55 (2), 173–184.
18. McRae, W.M., Thomson, N.R. (2000) VLF phase and amplitude: daytime ionospheric parameters. *J. Atmos. Sol.-Terr. Phys.* 62, 609–618.
19. Thomson, N.R.; Clilverd, M.A.; Rodger, C.J. (2017) Midlatitude ionospheric D region: Height, sharpness, and solar zenith angle. *J. Geophys. Res. Space.* 122, 8933–8946.
20. Nina, A., Nico, G., Mitrović, S.T., Čadež, V.M., Milošević, I.R., Radovanović, M., Popović, L.Č. (2021) Quiet Ionospheric D-Region (QIonDR) Model Based on VLF/LF Observations. *Remote Sens.* 13, 483.
21. McRae, W.M., Thomson, N.R. (2004) Solar flare induced ionospheric D region enhancements from VLF amplitude observations. *J. Atmos. Sol.-Terr. Phys.* 66, 77–87.
22. Thomson, N.R., Rodger, C.J., Cliverd, M.A. (2005) Large solar flares and their ionospheric D region enhancements. *J. Geophys. Res.* 110, A06306.
23. Nina, A., Čadež, V.M. (2014) Electron Production by Solar Ly-α Line Radiation in the Ionospheric D-region. *Adv. Space Res.* 54, 7, pp. 1276–1284
24. Bajčetić, J., Nina, A., Čadež, V.M., Todorović, B.M. (2015) Ionospheric D-Region Temperature Relaxation and Its Influences on Radio Signal Propagation after Solar X-Flares Occurrence. *Thermal Sci.* 2015, 19, S299–S309.
25. Thomson, N.R., Rodger, C.J., Clilverd, M.A. (2011) Daytime D region parameters from long-path VLF phase and amplitude. *J. Geophys. Res.* 116, 11305–11310.
26. Šulić, D.M., Srećković, V., Mihajlov, A.A. (2016) A study of VLF signals variations associated with the changes of ionization level in the D-region in consequence of solar conditions. *Adv. Space Res.* 57. 1029-1043.
27. Srećković, V.A.; Šulić, D.M.; Ignjatović, L.; Vujčić, V. (2021) Low Ionosphere Under Influence of Strong Solar Radiation: Diagnostics and Modeling. *Appl. Sci.* 11, 7194.
28. Feng, J., Han, B., Gao, F., Zhang, T., Zhao, Z. (2021) Analysis of Global Ionospheric Response to Solar Flares Based on Total Electron Content and Very Low Frequency Signals. *IEEE Access*, vol. 9, pp. 57618-57631.
29. Hayes, L.A., O'Hara, O.S.D., Murray, S.A., Gallagher, P.T. (2021) Solar Flare Effects on the Earth's Lower Ionosphere. *Sol. Phys.* 296, 157.
30. Nina, A., Cadež, V.M., Bajcetic, J., Mitrovic, S.T., Popovic, L.C. (2018) Analysis of the relationship between the solar X-ray radiation intensity and the D-region electron density using satellite and ground-based radio data. *Sol. Phys.* 293, 64.

31. Koen, E.J., Collier, A.B. (2013) Mid-latitude ionospheric signature of a weak solar flare in winter. *S. Afr. j. sci.* vol.109, n.1-2.
32. Bouderba, Y., NaitAmor, S., and Tribeche, M. (2016), Study of the solar flares effect on VLF radio signal propagating along NRK-ALG path using LWPC code, *J. Geophys. Res.* 121, 6799– 6807,
33. Nina, A.; Čadež, V.; Šulić, D.; Srećković, V.; Žigman, V. (2012B) Effective electron recombination coefficient in ionospheric D-region during the relaxation regime after solar flare from 18 February 2011. Nucl. Instrum. *Methods Phys. Res. B* 279, 106–109.
34. Nina, A., Čadež, V., Srećković, V.A., Šulić, D. (2011) The influence of solar spectral lines on electron concentration in terrestrial ionosphere. *Baltic Astron.* 20, 609–612.
35. Kolarski, A., Grubor, D., Šulić, D. (2011) Diagnostics of the solar X-flares impact on the lower ionosphere through the VLF-NAA signal recordings. *Baltic Astron.* 20, 591–595.
36. Šulić, D., Srećković, V. A. (2014) A comparative study of measured amplitude and phase perturbations of VLF and LF radio signals induced by solar flares. *Serb. Astron. J.* 188, 45–54.
37. Todorović Drakul, M., Čadež, V. M., Bajčetić, J. B., Popović, L. Č, Blagojević, D. M., Nina, A. (2016) Behaviour of Electron Content in the Ionospheric D-Region During Solar X-Ray Flares. *Serb. Astron. J.* 193, 11–18.
38. Chakraborty, S., Basak, T. (2020) Numerical analysis of electron density and response time delay during solar flares in mid-latitudinal lower ionosphere. *Astrophys. Space Sci.* 365.
39. Gavrilov, B., Ermak, V., Lyakhov, A. Poklad, Y., Rybakov, V., Ryakhovskiy, I. (2020) Reconstruction of the Parameters of the Lower Midlatitude Ionosphere in M- and X-Class Solar Flares. *Geomagnetism and Aeronomy*, 60. 747-753.
40. Basak, T., Chakrabarti, S.K. (2013) Effective Recombination Coefficient and Solar Zenith Angle Effects on Low-latitude D-region Ionosphere Evaluated from VLF Signal Amplitude and its Time Delay During X-ray Solar Flares. *Astrophys. Space Sci.* 348, 2, pp. 315–326.
41. Pandey, U., Singh, B., Singh, O.P., Saraswat, V.K. (2015) Solar flare induced ionospheric D-region perturbation as observed at a low latitude station Agra, India. *Astrophys Space Sci*. 357:35.
42. Rozhnoi, A., Solovieva, M., Fedun, V., Gallagher, P., McCauley, J., Boudjada, M.Y., Shelyag, S., Eichelberger, H.U. (2019) Strong influence of solar X-ray flares on low-frequency electromagnetic signals in middle latitudes. *Ann. Geophys.* 37, 843–850.
43. Nina, A., Čadež, V., Srećković, V.A., Šulić, D. (2012a) Altitude distribution of electron concentration in ionospheric D-region in presence of timevarying solar radiation flux. *Nucl. Instrum. Methods B* 279, 110–113.

44. Palit, S., Basak, T., Mondal, S.K., Pal, S., Chakrabarti, S.K. (2013) Modeling of very low frequency (VLF) radio wave signal profile due to solar flares using the GEANT4 Monte carlo simulation coupled with ionospheric chemistry. *Atmos. Chem. Phys.* 13, 9159–9168.
45. Tanaka, Y.T. (2010) VLF observations of magnetar flares. *AIP Conf. Proc.* 1286, 331–338.

The influence of solar Lyα and X radiation on the ionospheric D-region: the importance of determination of the quiet ionosphere parameters

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Solar radiation plays a very important role in photo-ionization processes in the ionospheric D-region. In the quiet conditions, hydrogen Lyα photons are the dominant source in the production of free electrons in the upper D-region, while the increase of X-ray flux during solar X-ray flares can cause very intense plasma disturbances of this atmospheric layer. In this paper, we present modelling of the quiet D-region electron density using the Quiet Ionospheric D-region (QionDR) model that incorporates variations in the influence of the Lyα photons during different periods of a solar cycle, year, and daytime. This model also allows more precise modeling of the perturbed D-region parameters during the influence of solar X-ray flares. Namely, a very important influence in this modeling has the determination of the quiet ionosphere parameters before perturbation. This study is based on D-region observations by very low / low frequency (VLF/LF) signals. In the presented analyse, we use the data recorded by the receiver located in Belgrade, Serbia, and related to the VLF signals emitted by the DHO and ICV transmitters from Germany and Italy, respectively.

Phoenix spectra for determination of the fundamental stellar parameters

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We present a set of calculated spectra for stellar atmospheres. Temperature is varied from 2500-10000K, log g from 0.5 to 5.5, z from 0.5 to 2.5 and alpha enhancment -0.2 to +0.8. Our aim is to use these spectra as the basis for the principal component analysis and determination of the fundamental stellar parameters.

Demonstration of the EARLINET Capacity to Provide Near Real Time Data

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The European Aerosol Research Lidar Network, EARLINET, was established in 2000 with the goal of creating a quantitative, comprehensive, and statistically significant database for the horizontal, vertical, and temporal distribution of aerosols on a continental scale [1]. EARLINET is part of ACTRIS (Aerosols, Clouds and Trace gases Research Infrastructure) a pan-European initiative consolidating actions amongst European partners producing high-quality observations of atmospheric aerosols, clouds and trace gases. Aerosol lidars with their high temporal and vertical resolution, provide reliable information on the atmospheric structure, its dynamics, and its optical properties. The Belgrade lidar station [2] participated in the several campaigns providing vertical aerosol profiles measurements which were submitted and processed by the Single Calculus Chain (SCC) in the near-real time (NRT). The SCC is a tool for the automatic analysis of aerosol lidar measurements developed within EARLINET network [3,4]. The main aim of SCC is to provide a data processing chain that allows all EARLINET stations to retrieve, in a fully automatic way, the aerosol backscatter and extinction profiles together with other aerosol products. Beyond the scientific goals of this campaign, the actions organized by EARLINET/ACTRIS (NRT delivery of the data and fast analysis of the data products) proved that aerosol lidars are useful for providing information not only for climatological purposes, but also in emergency situations [5].

References

[1] Pappalardo, G., Amodeo, A., Apituley, A., Comeron, A., Freudenthaler, V., Linné, H., Ansmann, A., Bösenberg, J., D'Amico, G., Mattis, I., Mona, L., Wandinger, U., Amiridis, V., Alados-Arboledas, L., Nicolae, D., and Wiegner, M., 2014. EARLINET: towards an advanced sustainable European aerosol lidar network, Atmospheric Measurement Techniques 7, 2389–2409.

[2] Ilić, L., Kuzmanoski M., Kolarž P., Nina A., Srećković V., Mijić Z., Bajčetić J., Andrić M., 2018. Changes of atmospheric properties over Belgrade, observed using remote sensing and in situ methods during the partial solar eclipse of 20 March 2015, Journal of Atmospheric and Solar-Terrestrial Physics171,250-259.

[3] D'Amico, G., Amodeo, A., Baars, H., Binietoglou, I., Freudenthaler, V., Mattis, I., Wandinger, U., and Pappalardo, G., 2015. EARLINET Single Calculus Chain – overview on methodology and strategy, Atmospheric Measurement Techniques 8, 4891-4916.

[4] D'Amico, G., Amodeo, A., Mattis, I., Freudenthaler, V., and Pappalardo, G., 2016. EARLINET Single Calculus Chaintechnical– Part 1: Pre-processing of raw lidar data, Atmospheric Measurement Techniques 9, 491-507.

[5] Papagiannopoulos, N., D'Amico, G., Gialitaki, A., Ajtai, N., Alados-Arboledas, L., Amodeo, A., Amiridis, V., Baars, H. et al., 2020. An EARLINET early warning system for atmospheric aerosol aviation hazards, Atmospheric Chemistry and Physics 20, 10775–10789.

Usage of High-Resolution Satellite Products in Atmospheric modeling

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Aerosol optical depth (AOD) is one of the most important aerosol products retrieved from satellite measurements, and represent the attenuation of solar radiation caused by aerosols. The direct radiative effect due to aerosol–radiation interactions is the change in radiative flux caused by the combined scattering and absorption of radiation by anthropogenic and natural aerosols. Due to their short lifetime and the large variability in space and time atmospheric aerosols are considered one of the major uncertainties in climate forcing and atmospheric processes [1]. The relationship between AOD (integration of the aerosol extinction coefficient from the Earth's surface to the top of the atmosphere) and surface aerosol concentrations depends on various factors: aerosol type and its chemical composition, vertical distribution, spatial and temporal variability. In this study the potential of Level 2 AOD data at 0.55 μm based on measurements by Moderate Resolution Imaging Spectroradiometer (MODIS) aboard Terra (MOD04) and Aqua (MYD04) platforms for PM modeling will be discussed [2]. In addition, recently lunched ESA Aeolus mission products intended for assimilation in Numerical Weather Prediction (NWP) models in Near-Real-Time together with its optical products will be introduced.

References

[1] IPCC (2007), IPCC Fourth Assessment Report Climate Change 2007 - The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the IPCC

[2] Fu, D., Xia, X., Wang, J. et al. Synergy of AERONET and MODIS AOD products in the estimation of PM2.5 concentrations in Beijing. Sci Rep 8, 10174 (2018).

Tracking and Processing Real-Time Astronomical Transients

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Running and upcoming big astronomical surveys offer immediate data access in a sense that a significant astronomical event can be processed in (near) real-time. Events are most frequently organized in data streams and may have a heterogeneous structure, and there is also legacy data which can be cross-matched. We review different "brokers", software tools for analyzing real time astronomical data streams.

Investigation and modeling of the free-electron density and temperature during the formation of laser-induced breakdown of plasma in air at various laser parameters

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The free-electron density equation and two temperature coupled equations during laser-induced ablation of air at atmospheric pressure are solved. In doing so, calculations were carried out to determine the comparative contribution of the mechanisms responsible for electron gain and losses in LIB of air. The solutions are initially obtained for the energy sources with a Gaussian distribution to describe the contribution of different pulse-width regimes. More general results provided in this study maintain the appealing aspects of other approximate solutions and reduce them under the respective conditions. Obtained results agree well with the numerical and experimental observations reported in the literature.

Atomic structure of the doubly ionized titanium Ti III ion

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In this work, we calculated *ab initio* and semi-empirically energy levels, lifetimes, oscillator strengths and transition probabilities of the doubly ionized titanium by two methods: the first one is by adapting the wave-functions using the Hartree-Fock and the configuration interaction methods, and the second one is by adapting potential using the Thomas-Fermi-Dirac-Amaldi (TFDA) method.
Atomic structure codes are adapted to give the lifetimes of the considered energy levels by inversing the sum of the dipole transition probabilities. The calculated atomic structure parameters of the Ti III ion are compared with NIST database and with other available data.

Stark broadening parameters of the singly ionized sulfur S II ion

Walid F. Mahmoudi[1], Lamia Abu El Maati[2,3], Sahar G. Tawfik[3,4], Fatemah H. Alkallas[4], Nabil Ben Nessib[5], Sylvie Sahal-Bréchot[6] and Milan S. Dimitrijević[6,7]

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In this work, we are interested by the calculation of Stark broadening widths of several singly ionized sulfur S II spectral lines by two methods:

For the first method, we used the semi-classical theory. In this formalism, Stark broadening of isolated lines are calculated in the impact approximation; semi-classical formulae were provided, including both dipole and quadrupole terms in the expression of electrostatic interaction between the optical electron and the perturber.

The theoretical values of Stark widths are calculated using energy levels and oscillator strengths of S II from the COWAN, AUTOSTRUCTURE and CIV3 atomic structure codes and from NIST database.

For the second method, we used the modified semi-empirical (MSE) formalism Dimitrijević *et al.* (1980).

We compared the calculated Stark parameters with available data from the literature.

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