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Guest Editorial

Special Issue on Spectral Line Shapes in Astrophysics

The analysis of spectral lines from various astrophysical sources can be a powerful tool to collect data on various properties of objects from the solar system to the most distant quasars. For example, on the basis of observed spectra one can perform diagnostics, analysis and modelling of various astrophysical objects from interstellar clouds of molecular hydrogen to neutron stars and quasars, in order to determine the chemical composition of stellar atmospheres and even obtain information on thermonuclear processes in stellar interiors. Moreover, Doppler broadening can give us information about the kinematical properties of emission gas. Conditions in the astrophysical plasma, temperatures and densities of different particles, are within much wider ranges than in the laboratory plasma, therefore, the lines from X-ray (Fe K) to the radio domain (radio recombination lines) have been observed. To understand the physical environment in which spectral lines are originating from cosmological sources, astronomers need the corresponding reliable atomic and molecular data and precise laboratory measurements of spectral line properties. Therefore, interaction between astrophysicists and laboratory physicists who investigate spectral lines originating from cosmological sources can provide a boost to our understanding of the Universe. Accordingly, the main objective of this conference on 'Spectral Line Shapes in Astrophysics' was to bring astronomers and physicists together.

Laboratory spectral line shape investigations in Serbia and former Yugoslavia began in the sixties of the last century. Now such research is also being carried out in Belgrade Astronomical Observatory, Institute of Physics and Faculty of Physics, Belgrade University and in Faculty of Sciences, University of Novi Sad.

In Serbia, there have been nine conferences on spectral line shapes between 1995 and 2013 and each of these proceedings have been published and documented. Interestingly, it was during the fourth conference in 2003 that organizers realized that astronomers formed a prinicipal group in this series of conferences and consequently, the topic of 'astrophysics' was added to all further conferences on 'spectral line shapes' thereafter. We were enthused, therefore, to organize a spectral line shape conference in Serbia.

This Special Issue comprises selected papers presented at the X Conference on 'Spectral Line Shapes in Astrophysics' at Srebrno Jezero, Serbia during 15th–19th June 2015. This international conference was attended by 69 participants from Algeria, Austria, Bulgaria, Croatia, France, Greece, Israel, Italy, Japan, New Zealand, Poland, Republic of Srpska (Bosnia and Herzegovina), Russia, Saudi Arabia, Serbia, Spain, Tunisia, UK, Ukraine and USA. There were 27 invited lectures, 19 progress reports and 32 posters. As part of the conference, two special sessions entitled "Line

Shifts in Astrophysics" and "Spectral Lines and Compact Stars" within the frame of the COST Action MP 1304 "Exploring Fundamental Physics with Compact Stars" were also organized.

The papers in this special issue have been arranged subject-wise in three groups. Papers of the first group investigate shapes of spectral lines formed in galaxies. In the second group, there are two papers dealing with spectral line shapes from geo-cosmical plasmas while the papers of the third group are devoted to laboratory astrophysics. They deal with spectral line shapes and consider theoretical aspects and the influence of atomic and molecular collisional processes on spectral line profiles. A brief description of important results presented in each paper of this special issue is given below:

In the first group, the paper by Nick Devereux reviews Hubble Space Telescope (HST) spectroscopy of a remarkable population of dwarf Seyfert galaxies with an unusually large broad line region (BLR). These objects represent a new class of active galactic nuclei (AGN) that is yet to be recognized as such by the astrophysics community. The AGN spectral variability enables us to study in depth the structure of AGN emitting regions. In particular, the variations observed in flux and shape of broad line profiles give us invaluable information about the kinematics and geometry of the BLR. The paper by D. Ilić *et al*. presents astrophysical results based on the observed line shape variability of a sample of AGN. These spectra and broad-line profiles are obtained from the long-term optical monitoring campaign performed with the telescopes of Special Astronomical Observatory (Russia), INAOE and OAN-SPM (Mexico). They studied the physics and kinematics of the BLR, focusing on the problems of the photoionization heating of the BLR and its geometry. The paper by Giovanni La Mura *et al.*, presents important astrophysical results on extra-galactic γ-ray sources whose AGN class is still unknown. For this study, the authors carried out a campaign and obtained their optical spectroscopic observations. The paper discusses the implications of such a large scale study of γ-ray emitting AGNs. Mary Loli Martínez-Aldama *et al.* present spectroscopic observations of intermediate redshift quasars obtained with the Infrared Spectrometer And Array Camera (ISAAC) on the ESO Very Large Telescope, covering the region of OI 8446 Å and the Ca II triplet 8498, 8542, 8662 Å and almost doubled the number of intermediate redshift quasars having such Ca II observations. This work based on a statistically significant sample provides valuable information on low-ionization line formation and recent episodes of star formation in the intermediate redshift quasars. An analysis of X-ray spectra of quasars has been carried out by K. Bensch *et al*. using the 4D Eigenvector 1 parameter space which serves as a surrogate H-R diagram for representing empirical diversity among quasars and identifying the physical drivers for the same. Light curves of the continuum and emission lines of five type 1 active galactic nuclei (AGN) have been investigated by A. Kovaćević *et al.* in order to test time-evolution of their time delays using both modeled and observed AGN light curves. In all objects, the largest variations in time delays occurred during the period when continuum or emission line luminosity was highest. D. Stathopoulos *et al.* used a method of multicomponent analysis in the complex profiles of high ionization UV doublets broad absorption resonance lines of Si IV and C IV in the spectra of J01225+1339 and J02287+0002. This paper highlights the physics used by this method and the uniqueness of the number of components needed for reproduction of complex line profiles. The formation of spectral line shapes in the

vicinity of supermassive black holes present in the center of galaxies and AGN are discussed in the next three papers. M. Smailagić and E. Bon model the formation of Balmer line emission in inner spiral structures formed by the orbiting motion of symmetric binary black hole systems (BBHS) in the merger cores, assuming that the line emission is produced by photo ionization of the gas in spiral structures by each black hole's mini accretion disk radiation, while M. Grzedzielski *et al.* investigate the problem of stochastic versus deterministic nature of the black hole binaries radiation, using both observations and analytical methods. The third paper by A. F. Zakharov discusses the possibility of the presence of an ordinary supermassive black hole at the galactic center. He used mm-band with VLBI radio observations to determine parameters like orbits of bright stars near the Galactic Center. In order to explain these observed parameters, the author has proposed new theories.

The second group of manuscripts are devoted to spectroscopic investigations of geo-cosmical plasmas. There are only two papers in this group. The review paper by G. Peach examines the broadening of radio recombination spectral lines formed in interstellar hydrogen clouds using impact theory and finds that the existing discrepancy between the observations and theory remained unresolved. A. Kolarski and D. Grubor present a comparative analysis of Very Low Frequency (VLF) signal traces, propagating from Skelton (UK) and Maine (USA) toward Belgrade, induced by four isolated solar X-ray flare events that occurred during September 2005 to December 2006. The considered solar flare events induced lower ionosphere electron density height profile changes, causing perturbations in VLF wave propagation within Earth–ionosphere waveguides, and the propagation parameters along trajectories from their transmitters to the Belgrade receiver site were affected in different ways.

The third group, containing 11 papers is devoted to laboratory astrophysics which deals with spectral line shapes and the influence of atomic and molecular collisional processes on profiles of spectral lines in laboratory and astrophysical plasmas. J. Rosato *et al.* report on recent investigations of hydrogen spectral lines in magnetized plasmas motivated by controlled fusion research, which are also of interest for astrophysical problems so that the applicability of presented models to the diagnostic of plasma in white dwarf atmospheres can be explored. A. N. Veklich *et al.* present a selection of W I, Mo I and Cr I spectral lines and appropriate spectroscopic data for the purposes of laboratory and stellar plasma diagnostic. J. Rosato revisits the radiative transfer theory from a first principles approach, inspired from the Bogoliubov–Born–Green–Kirkwood–Yvon (BBGKY) hierarchy of equations, and performed calculations of absorption lines in stellar atmosphere conditions. K. N. Arefieff *et al.* discuss the specific features of the dynamic resonances formalism in excited atomic states of astrophysical interest including the observed features in the fluorescence spectrum. Moreover, an explanation of the abnormal properties of the IR emission spectra of white dwarfs which reveal a gap in the radiation emitted by Rydberg atoms (RA) with values of the principal quantum number of $n \approx 10$ is given. A. A. Mihajlov *et al.* review and discuss the inelastic processes in atom Rydberg-atom collisions, such as chemi-ionization and $(n - n')$ mixing, concluding that they should be considered all together. H(1s) + H*(n) ($n \gg 1$) collisional systems are very useful for understanding the spectra of Sun and Sun type stars. The importance of this work for helium-rich white dwarfs has been investigated. The article by A. A. Mihajlov, V. A. Srećković & N. M. Sakan studies the influence of electron-ion inverse Bremsstrahlung on the opacity of the different stellar atmospheres and

astrophysical plasmas. The broadening induced due to electron and ion impacts with atoms and ions (Stark broadening) in the spectra of stars are investigated in the next four papers. Using the semi-classical perturbation method, Milan S. Dimitrijević *et al.* calculate Stark broadening parameters of spectral lines of Ne I while N. Alonizan *et al.* determine widths and shifts of O I spectral lines. In order to understand the influence of Stark broadening on the spectra of A-type stars, Zlatko Majlinger *et al.* calculate the Stark broadening of Lu III spectral lines using the modified semi-empirical method, while Milan S. Dimitrijević *et al.* provide new results for the Stark widths and shifts for Xe VI spectral lines which are of interest for investigations of compact stars like white dwarfs. The new Stark broadening parameters, reported in these four papers will be entered in the STARK-B database (http://stark-b.obspm.fr/) which contains results of such calculations reported earlier. It is pertinent to mention here that the STARK-B database is included in the new search facility for such data namely Virtual Atomic and Molecular Data Center (VAMDC – http://vamdc.org/) and also has a link in Serbian Virtual Observatory (SerVO – http://servo.aob.rs/).

The last paper of this special issue by V. Vujčić *et al.* is a report on the Belgrade MOL-D database, a repository of cross-sections and rate coefficients for specific collisional processes and a web service within the VAMDC and SerVO. Actually, this contains data for photo-dissociation + cross-sections of hydrogen and helium molecular ions and the corresponding average thermal photo-dissociation cross-sections for the relevant temperature range. The MOL-D can also be accessed directly at http://servo.aob.rs/mold or through VAMDC portal. Thus all these scientifically valuable data are available on-line to the scientific community.

This special issue of *Journal of Astrophysics and Astronomy* contains valuable reviews which are of interest to specialists and PhD students. It also includes scientific papers with results of new research on the topics related to the subject matter. The results of investigations presented in this issue will therefore contribute to the development of our understanding of spectroscopy of active galactic nuclei, spectra connected with black holes and interstellar hydrogen clouds. Results of modeling of spectral lines presented in this special issue may be very useful for future investigations of compact star, in particular of white dwarfs. Similarly, new theoretical Stark broadening parameters of spectral lines of Ne I, O I, Lu III and Xe VI could be important not only for modeling, analysis and synthesis of stellar spectra but also for various applications in laboratory plasma research as well as for inertial fusion and plasmas in technology, such as laser welding and piercing of metals and light sources based on plasma. We, therefore, are confident that this special issue will be useful and interesting to scientists working in this field and will contribute to further development of astrophysical and laboratory spectra research. The review articles will especially be valuable to young researchers and PhD students engaged in similar areas of research.

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Conference photo of the X Conference on ‘Spectral Line Shapes in Astrophysics’
at Srebrno Jezero, Serbia during 15–19 June 2015.