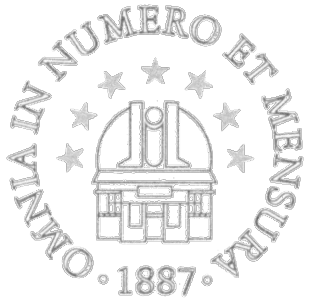
XIV Serbian Conference on Spectral Line Shapes in Astrophysics

BOOK OF ABSTRACTS

Editors: Luka Č. Popović, Nataša Bon, Edi Bon and Sylvie Sahal-Bréchot



Belgrade, 2023

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EXPLORING THE JET-BLR CONNECTION: FLARE-INDUCED VARIABILITY IN THE OPTICAL EMISSION LINES

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Relativistic jets are among the most important players in the feedback processes between active galactic nuclei (AGN) and their host galaxies. By propagating through the interstellar medium, they can transfer part of their energy into the gas and heating it up, or produce compression shocks that eventually induce star formation. In a few cases, during relativistic jets' flares, the innermost part of the AGN seems to be affected. The broad-line region (BLR), indeed, can respond to the flares, by increasing (or decreasing) the line luminosity. To date, only a handful of sources have shown this behavior, mostly powerful flat-spectrum radio quasars, such as CTA 102, 3C 454.3, and 3C 345. Howeve, this phenomenon was recently observed for the first time in a jetted narrow-line Seyfert 1 galaxy, PKS 2004-447. The source underwent a gamma-ray flare in 2019, which altered the BLR and produced a flux excess redshifted by 250 km/s, and observed by the X-shooter instrument in the Balmer, Paschen, and He I permitted lines. This new emission feature was no longer visible 1.5 years later, suggesting a causal connection with the flare. The emission lines coming from the same atomic transition series show a similar velocity offset for this "red excess", but the offset changes for different line series. This discovery suggests that the relativistic jet can affect the physics of the BLR in all classes of jetted AGN, and that flaring activity can lead to the formation of additional and localized broad emission components. Our results highlight the importance of optical spectroscopy for flaring jetted AGN, and that our understanding of the jet-BLR -connection is still very limited.

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STUDY OF THE STATISTICAL AND RADIATIVE PROPERTIES OF DENSE PLASMA

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The radiative properties of an ion surrounded by a plasma are modified by various mechanisms. One of them, the ionization potential depression (IPD) affects both the radiative properties of the different ionic states and their populations. It is due to the surrounding charges of the radiator which contribute to the lowering of the energy necessary to free an electron in the ground state. Two distinct models, namely Stewart-Pyatt (Stewart and Pyatt, 1966) and Ecker-Kröll (Ecker G and Kröll W 1963) models are widely used to estimate IPD.

An approach based on classical molecular dynamics simulation has been developed providing an alternative way to calculate the IPD (Calisti A, et al. 2015). Ions and electrons are treated as classical particles and some quantum properties are taken into account through a regularized potential allowing to model collisional ionization and recombination processes. The related numerical code, BinGo-TCP, has been designed to describe neutral mixtures composed of ions of the same atom with different charge states, and electrons. Within the limits of classical mechanics, all charge-charge interactions are accounted for in the particle motion.

In this work, the importance of the choice of the IPD modeling will be emphasized through a study of some dense plasma radiative properties. We will also discuss the ionization energy distributions obtained with BinGo-TCP due to the fluctuating environment of the ions.

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MULTI-MESSENGER SEARCHES FOR SUPERMASSIVE BLACK HOLE BINARIES

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Supermassive black hole binaries (SMBHBs) are a natural end product of galaxy mergers and should be common in galactic nuclei. They produce bright electromagnetic emission and can be identified as quasars with periodic variability in time-domain surveys. They are also promising sources of low-frequency GWs soon to be detected by pulsar timing arrays (PTAs) with PTAs and time-domain surveys probing the same population of binaries. I will summarize the status of searches for quasars with periodic variability and prospects for discovery with the Legacy Survey of Space and Time of the Rubin Observatory. I will also discuss the combination of time-domain observations with PTA data in a multi-messenger stream, the parameter space of binaries for which this combination is possible and the advantages of multi-messenger observations (e.g., improved parameter estimation).

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COMPLEX LINE SHAPES IN NON-THERMAL LABORATORY PLASMA

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Non-thermal, or cold, atmospheric 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. Optical emission spectroscopy is systematically applied to the task of obtaining data on plasma parameters and processes. However, the non-equilibrium nature, space inhomogeneity and transient nature of these plasmas pose limitations on line profile analysis. In addition, similarly to astrophysical plasmas, complex spectral line shapes are occasionally observed, that cannot be explained using standard models for line shape analysis e.g. Doppler or pressure broadening. To perform line analysis in such cases, new and advanced fitting procedures must be developed, often paired with fast imaging and electrical measurement to complete the unknowns in the method. In this presentation we will show several experimental studies of non-thermal plasma which use complex atomic line profiles, both from hydrogen and non-hydrogen spectrum. It will be shown how the inhomogeneity of plasma in time in space, presence of strong sheaths and line-of-sight effects are mirrored in the shape of the spectral line.

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KINEMATICS OF THE IONIZED GAS IN NEARBY GALAXIES AS DIAGNOSTICS OF THE ENERGY BALANCE BETWEEN ISM AND MASSIVE STARS

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Stellar feedback is a key contributor to the regulation of the morphology and dynamics of the interstellar medium in star-forming galaxies. Integral-field spectroscopy of nearby galaxies reveals signatures of ubiquitous supersonic motions of the ionized gas manifesting themselves in broadening or asymmetries of bright emission lines. The study of expanding ionized superbubbles and turbulent gas motions producing these features enables quantitative constraints to be placed on the energetics of stellar feedback. I will present the analysis of the small-scale ($\sim 30-500$ pc) ionized gas kinematics in very nearby dwarf galaxies ($D < 5$ Mpc, mostly from Local and M81 groups) and more distant spiral galaxies ($D = 8 - 20$ Mpc, from PHANGS survey) based on their observations with the scanning Fabry-Perot interferometer at the 6-m BTA and with the integral-field spectrograph MUSE at the 8-m VLT telescopes. We found $\sim$ 1500 regions of locally elevated velocity dispersion and argue that stellar feedback is the dominant source for powering the ionized gas in these regions, with a typical efficiency of 10-20%, in agreement with hydrodynamical simulations. Accounting for pre-supernovae feedback is required to set up the energy balance between gas and stars in these dynamically active regions. The measured kinetic energy of the ionized gas of superbubbles and turbulent gas motions decreases with metallicity reflecting the lower impact of stellar feedback in a low-metallicity environment.

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COMPUTER SIMULATION OF THE EFFECT OF PERIODIC ELECTRIC FIELDS ON LINE SHAPES

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Plasma diagnostics using Stark-broadened spectral line shapes require an increasing accuracy to obtain detailed information on the physical processes at work in the plasma. In a complementary way to the analytical approaches, computer simulations have been used in the last decades in an attempt to increase the accuracy of the line shape models, e.g. to study an improved treatment of N-body interactions by using molecular dynamics [1,2], and the effect of non-dipole terms or the interaction of the plasma particles within the wave function extent of the bound electron [3,4].

We here use a computer simulation for accurate line shape calculations of hydrogen submitted to the simultaneous effect of the plasma microfield and a periodic electric field. Periodic electric fields can be generated by an external source, such as a microwave generator or laser radiation, but they may also be created inside the plasma, resulting from a nonthermal effect driven by a plasma instability. Our simulation generates classical particles moving in a cubic box with straight paths for the case of neutral emitters. Velocities are sampled from a Maxwellian distribution, and periodic boundary conditions ensure that the number of particles remains constant.

Using a dipolar approximation, we integrate the emitter Schrödinger equation by bretaining the simultaneous effects of the microfield and a periodic electric field $\vec{E}_W = \vec{E}_L \cos(\omega t + \varphi)$, with φ a random phase, and a field magnitude E_L of the order of or larger than the average plasma microfield.

We present simulated Lyman and Balmer line shapes for plasma densities and temperatures corresponding to many laboratory, fusion and astrophysical plasma.

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OPTICAL AND X-RAY COUNTERPART OF SUBPARSEC SUPERMASSIVE BINARY BLACK HOLES

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In order to study the optical and X-ray counterparts of subparsec supermassive black hole binaries (SMBHBs) in the profiles of optical spectral lines emitted from the broad line region (BLR), as well as from the X-ray spectral lines emitted from the relativistic accretion disks around both components, here we simulated such profiles and compared them with each other. For that purpose, we assumed a realistic set of orbital elements and mass ratios for such a SMBHB and used them to simulate the corresponding composite Hβ spectral line in the optical band and the Fe Kα line in the X-ray band. The Hβ line is assumed to come from two BLRs that follow the dynamics of component motions and an additional circumbinary BLR that surrounds the SMBHB system (see Popović et al. 2021). Regarding the X-ray band, we studied the composite Fe Kα line using the ray tracing method in Kerr metric, assuming that both accretion disks around primary and secondary give a significant contribution to the total Fe Kα line emission of such a SMBHB (see Jovanović et al. 2020 and references therein). The obtained results showed that SMBHBs could cause a specific, but different variability of the both Hβ and Fe Kα lines, leaving potentially detectable

imprints in their profiles. Since these imprints depend on the orbital phase of the system, they could be used for reconstructing the Keplerian orbits of the components in the observed SMBHBs. Moreover, such signatures in the optical and X-ray line profiles from the observed SMBHBs could be used as a tool for detection of these objects, as well as for studying their properties.

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APPLICATION OF DEEP-LEARNING TO LINE SPECTRA IN MAGNETIC FUSION PLASMAS

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This paper discusses the use of deep-learning, a subfield of artificial intelligence, in plasma physics in particular its coupling with spectral features of emission lines in magnetic fusion. In our previous work [1-2] we have demonstrated the proof-of-principle of a new technique to determine the isotopic ratio in hydrogen-deuterium fusion plasmas. In this technique, instead of fitting whole spectra, it is suggested to provide only some few spectral features to an artificial neutral network algorithm from TensorFlow platform [3] to infer the isotopic ratio in a hydrogen-deuterium plasma. In the present paper, we make a further step by confronting the technique to the more complex case of deuterium-tritium (DT) plasmas by considering features of the Dα/Tα line spectra. This complexity is due to the highest proximity of the Dα and Tα lines as compared to Dα and Hα which is not favorable in terms of Zeeman splitting for a same magnetic field strength. The paper discusses also in a more general manner the application of deep-learning techniques to emission lines in magnetic fusion plasmas.

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COLLISIONAL DATABASES WITHIN VAMDC: SYNERGY WITH RADAM and Nano-IBCT COST ACTIONS

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Although the idea of creating a collisional database that would cover cross section data for electron interactions with atomic and molecular targets existed for a long time at the Institute of Physics Belgrade, only after beginning of the COST Action P9 RADAM (acronym for Radiation Damage), *Radiation Damage in Biomolecular Systems*, it started to materialize. One of the important goals of RADAM that lasted four years, from 2003 till 2007, was to produce set of comprehensive databases which would cover different aspects of radiation damage. This idea was further developed within successor COST Action MP1002, *Nano-scale insights in ion beam cancer therapy (Nano-IBCT)*, when five distinctive areas of data collections (interactions of ions, electrons/positrons, photons, multiscale RADAM phenomena and radiobiological phenomena) were gathered into one RADAMDB portal. All those databases had been created using the Virtual Atomic and Molecular Data Center (VAMDC) standards. Adopting these standards and sharing the same idea of distributed nodes of individual databases both consortia, VAMDC and RADAMDB, became decisive provider of atomic and molecular data, relevant for many other fields of science and technology (astrophysics, plasma, lasers, lighting, radiation treatment). Presently there are 39 active nodes within VAMDC that comprise large national and international facilities dedicated to

provide accurate data (AMBDAS database, Cologne Database for Molecular Spectroscopy - CDMS, Harvard-Smithsonian Center for Astrophysics with HITRAN database, Atomic Spectra Database, Japan National Institute for Fusion Science – NIFS with its Atomic and Molecular Research Center, as well as databases from large international projects like Opacity or Iron project). Institute of Physics Belgrade became an important pillar of VAMDC holding at present two nodes: BEAMDB - Belgrade electron/atom(molecule) database and Photodissociation - MolD database with the prospect to add two more nodes, Collisional Atomic Processes (Excitation-Ionization) - ACol database and database with Judd-Ofelt parameters.

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RADIO-JETS AND IONIZATION CONES IN SEYFERT GALAXIES

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It is generally believed that radio-quiet active galactic nuclei (including the most of Seyfert galaxies) haven't large-scale radio-jets. However current observations reveal more and more objects showing both radiative (the ionization cone) and kinetic (extended radio jets) modes of activity. I briefly discuss examples of such galaxies, including our observations at the 2.5-m and 6-m Russian telescopes.

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GAIA AS AN AGN DISCOVERY MACHINE

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Gaia is a cornerstone mission of the European Space Agency, with the main goal of improving our understanding of the Milky Way galaxy and its evolution by providing epoch astrometry, photometry, spectrophotometry and spectroscopy for up to 2 billion sources. Because of the unbiased nature of the survey that covers the entire sky down to the magnitude of $G < 21$ and its high spatial resolution, it is also interesting for the extragalactic community. After a brief introduction to the technical aspects, the presentation will focus on some use cases of mission results that may be particularly relevant for AGN science.

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EMISSION LINE REGIONS IN ACTIVE GALAXIES: SELECTED STUDIES IN SPECTRAL LINE VARIABILITY IN THE ERA OF JWST AND LSST

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The study of the line-emitting regions in active galaxies (AGNs) has had a long and profound history - from the very first confirmation of the extragalactic origin of AGNs to reverberation mapping leading to the size determination of these regions, to now AGNs and quasars being used as "standardizable" cosmological candles to understand the evolution of our Universe. We have already entered the era of big telescopes, and with the early success of JWST and with the upcoming Vera C. Rubin Observatory's LSST, the future of exploration of AGNs across cosmic time is exciting. In this review, I will present some recent progress in AGN variability studies in preparation for the massive data surge with LSST. I will discuss some recent advancements from the AGN Polish Consortium side for the in-kind contribution to LSST. I will demonstrate how the research uses quasars for Cosmology and understand the nuances to calibrate them as standard candles, focusing primarily on the broad-line region size-luminosity relation and highlighting our recent advances to better understand this connection from various aspects - from spectroscopic studies to photoionization modeling to joint analyses with other cosmological probes. I will briefly review selected studies and how the combination of theoretical insights and advancements in telescope capabilities have allowed us to gain further insights into these captivating cosmic systems.

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DISSECTING MG II AND FE II EMISSION REGIONS IN INTERMEDIATE REDSHIFT QUASARS WITH SALT

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Active galactic Nuclei (AGN) host a supermassive black hole (SMBH) at the center surrounded by accreting materials falling into it. It also has gas clouds suspended just above the SMBH whose origins and structures are still unknown. The spectral information suggests these clouds are in motion around the SMBH. The central part is very dynamic which also shows sometimes the inflow and outflow of materials. We observe three intermediate redshift quasars with SALT for a spectroscopic study and performed a wavelength-resolved reverberation in order to understand the structure and the dynamic of the BLR clouds or infalling and outflowing materials. We developed first time ever the R-L relation for UV Fe II and compared it with optical Fe II and Mg II which helps us to disentangle their emission sites. I will elucidate more about the importance of our results and the inner structure of AGN.

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NIST ATOMIC DATABASES: DATA EVALUATION, UNCERTAINTIES, ONLINE TOOLS

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Atomic data is an important component of the Physical Reference Data program at the National Institute of Standards and Technology (NIST). For many decades, the NIST physicists were carrying out in-depth analysis and evaluation of the available atomic data in order to generate evaluated and recommended sets of various atomic parameters such as energy levels, transition probabilities, oscillator strengths and ionization potentials. The data are then propagated into freely accessible relational databases for dissemination and retrieval by researchers around the world. In this talk an overview of the NIST atomic databases and online calculational tools will be presented with emphasis on the most recent developments.

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X-RAY FREE ELECTRON LASER DRIVEN RESONANCE PUMPING OF SPECTRAL LINES OF HIGHLY CHARGED IONS IN DENSE PLASMAS

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Atomic populations and line shapes belong to the fundamental quantities characterizing the spectral emission from plasma systems, thus being important for various disciplines in science and applications like radiation transport, astrophysics, fusion science, High-Energy-Density-Physics, diagnostics. E.g., radiation transport controls the energy balance and temperature profile in stars while opacity represents a key parameter to understand the evolution of various astrophysical objects [1,2]. In standard transport theory the opacity τ_ω is linked to the spectral distribution I_ω via the local source function S_ω that is the ratio between the local emission coefficient ϵ_ω and the absorption coefficient $S_\omega{=}\epsilon_\omega/\kappa_\omega$ while ϵ_ω and κ_ω themselves are the sum of the bound-bound, bound-free and free-free contributions, i.e. $\epsilon_\omega = {\epsilon_\omega}^{bb} + {\epsilon_\omega}^{bf} + {\epsilon_\omega}^{ff}$ and $\kappa_\omega = {\kappa_\omega}^{bb} + {\kappa_\omega}^{bf} + {\kappa_\omega}^{ff}$ [1,3]. Therefore, the emission and absorption line profiles impact not only to the bound state properties but to the continuum ones too.

The calculation of X-ray line shapes in dense plasmas is a discussion up to present days [e.g. 4-7, and references therein] and suffered from a lack of suitable experiments. The situation has changed with the development of X-ray Free Electron Lasers (XFEL's) providing intense and tunable photon sources with narrow bandwidths allowing resonance pumping of spectral lines up to 20 keV. Moreover, current installations [8-10] provide more that 10 orders higher photon flux compared to the most brilliant synchrotron sources. This allows to induce observable changes in the X-ray spectral emission because photon induced rates are competitive with other collisional-radiative processes even in dense plasmas [11].

The XFEL provides high near monochromatic photon flux that is not met in nature. However, it is this property that enables to produce fluorescence emission data capable to challenge dedicated parts in the theory. The present talk will outline the possibilities of current dense plasma experiments at XFEL installations and report the results of the first high-resolution X-ray spectroscopic experiments [12,13] where the intense XFEL beam was brought to interaction with a dense plasma that had been produced by the irradiation of a powerful auxiliary optical laser system.

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PROBING THE BLR GEOMETRY FOR QUADRUPLY LENSED QUASAR Q2237+0305 WITH MICROLENSING TIME SERIES

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The quadruply lensed quasar Q2237+0305 at $z = 1.695$, known as the Einstein cross, has been known for years to be a privileged laboratory for microlensing studies due to very short time lags. The spectra of the image A reveals a strong magnification effect that distorts the broad C IV emission line, while the image D shows no microlensing induced variability. The BLR microlensing is characterized with three observables (indices) calculated from the broad line: μ^{BLR}, WCI and RBI (Hutsemékers et al. 2019).

We model microlensing by convolving the magnification map with three representative BLR geometries: Keplerian disk (KD), polar wind (PW) and equatorial wind (EW). Variability is modeled by linear motion of a point source over the convolved images. We directly compare for which model parameters the extracted time series match with the observed indices. The preferred geometry is KD and the most likely BLR mean radius is 63 ± 20 light days (for C IV line). We discuss the possibilities of extending our method to other lensed quasars as well as large datasets.

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OPTICAL SPECTROPOLARIMETRY OF AGN: INSIGHTS ON ACCRETION DISK, BLR AND DUST SUBLIMATION

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AGN spectropolarimetry is a relatively new technique for studying the central regions of active nuclei, which has been intensively developing for several decades in both observations and numerical models. Polarized AGN spectra make it possible not only to penetrate the "dust curtain" in Sy 2 galaxies but also to obtain a significant amount of information about the structures in the central parsec of Sy 1s. In this report, we will present several most interesting observational results obtained by us in the last few years on BTA/SCORPIO-2, among which there are distant ($z > 1.5$) and gravitationally lensed quasars. The contribution presents how different polarization signatures in the continuum and broad emission lines are related to the mechanisms of polarization generation due to the accretion of disk magnetic fields or scattering in a medium beyond the BLR. Also, the up-to-date approaches to determining the physical parameters of AGN are shown concerning SMBH mass independent of the inclination angle, magnetic field strength, clues of Keplerian motion in BLR and dust sublimation region size.

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HIGH-REDSHIFT GALAXIES SPECTROSCOPIC DIAGNOSTICS

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If the characteristics of the extragalactic interstellar medium depend on the mechanisms of evolution of the host galaxy, the formation and evolution of galaxies also depend on the physico-chemical properties of their interstellar medium. We need to extract from the information conveyed in galaxies multi-wavelength spectral energy distribution (SED the parameters relevant to the galaxy evolution (star formation history, initial mass function, density, metallicity, cosmic ray, photoradiation field, ...) as the retroaction processes (galactic fountain, stellar feedback, AGN outlflow) from the epoch of re-ionization ($6 \leq z \leq 25$) to now ($z=0$), in order to interpret observations from existing observatories (ALMA, NOEMA, SPT, HST, JWST) and to prepare observations for future observatories (VLT/MOONS, Subaru/PFS, ELT/Mosaic, OST, PRIMA, ATHENA,...).

I will present how we combined photometry and spectroscopy (atomic and molecular lines) of H II regions to generate spectral templates on 2508 sources of the COSMOS field also observed with Subaru/FMOS in the range $0.6 \leq z \leq 1.6$. UV-to-MIR photometric data of the COSMOS2015 catalog are fitted with the CIGALE SED fitting code to get the stellar continuum emission and infer star formation rates and stellar masses. Then the nebular emission is added from libraries of CLOUDY models. A gas phase metallicity and a ionization parameter are assigned to each source and CIGALE iss run again to generate emission lines consistent with the UV-to-MIR continuum. I will also present how it is possible to constrain parameters relevant to photon dominated regions using IR emission line ratios and IR emission line diagnostic diagrams using the strongest IR lines such as $[O^{2+}]52$ μm, [O]63 μm and $[O^{2+}]88$ μm or $[C^{+}]158$ μm lines. I will then present work in progress on Active Galactic Nuclei broad and narrow line regions spectroscopy.

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WHAT THE SUBMM SPECTRAL LINE EMISSION IN THE NUCLEUS OF THE CIRCINUS GALAXY TELLS US ABOUT ACCRETION AND FEEDBACK IN AGN

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An Active Galactic Nucleus (AGN) is the manifestation of an actively accreting supermassive black hole in the centre of a galaxy. Submm and infrared interferometry allows us to resolve nearby AGN on parsec scales and to thus study the molecular and dusty material directly surrounding the supermassive black hole. Together with radiative transfer and hydrodynamical modelling, these observations have significantly advanced our understanding of this region crucial for the accretion onto the black hole as well as for the formation of outflows as part of feedback mechanisms.

I will present the results from observations with ALMA and the VLTI of the nearby Seyfert 2 nucleus of the Circinus Galaxy with a special focus on the submm line emission from molecular species such as CO, HCO^+, HCN, and CS. The submm molecular lines reveal a geometrically thin rotating disk of dense molecular gas with some additional velocity components indicating a filamentary structure. The gas gets denser and higher excited towards the centre, with only little signs of a molecular outflow. At the same time the galaxy has a clear ionized outflow. The infrared continuum observations also reveal a central, disk-like structure plus dust extended in the polar direction, the latter being seen as evidence for a radiation driven dusty outflow.

In summary, a clear two component structure is found, composed of a dense molecular and dusty disk plus a mainly ionised and dusty polar wind, i.e. in general agreement to recent radiative and hydrodynamical models.

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EXTREMELY HIGH-VELOCITY UV OUTFLOWS IN THE MOST LUMINOUS QSOS AT COSMIC NOON: DISCOVERY, IMPLICATIONS & PERSPECTIVES

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We are performing an investigation of ionized extremely high-velocity (∼0.1-0.3c) outflows (EHVOs) imprinting their signatures in the UV band of most luminous QSOs shining at Cosmic noon, finding them in 1 out of 10 quasars. Such large velocities imply large kinetic energy rate ($\propto v^3$), therefore EHVOs are believed to play a major role in communicating the huge SMBH accretion luminosity to the gas reservoir in the host. Broad absorption lines (BALs) probe quasar outflows originating from the inner regions around the black hole, providing us unparalleled insight in the structure of quasar central engines. Studying the variability of these BALs can help us to understand their structure, temporal evolution, and key physical properties. Remarkably, we have recently discovered a multi-component EHVO UV BAL in CIV line in an hyper-luminous quasar at z∼3.6 exhibiting complex variability in each component at five different epochs, spanning 17 yr in the observed frame. I will discuss the possible mechanisms responsible for the variability, which allow us to derive the location and kinematics of the outflow, and the role of these powerful EHVO UV outflows as a promising mechanism for feedback in luminous quasars. Finally the measured extreme velocities (∼0.2 c) in these BAL UFOs are similar to the UFOs typically observed in the X-ray spectra of local AGN. However, while X-ray UFOs require time consuming observations to be studied, the study of UV UFOs variability can be performed by routine observations even at high redshifts. I will briefly present an overview of future perspectives in this blooming research field.

PROGRESS REPORTS

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OPTICAL REVERBERATION MAPPING OF THE Fe II LINES IN NGC 4051

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Here we investigate the response time of the Fe II lines and optical continuum in the low luminosity Seyfert 1 galaxy NGC 4051. We analyze light curves of continuum and Fe II flux variation that we measured from publicly available spectra of the International AGN Watch monitoring campaign. Our preliminary results show that Fe II flux is correlated with the optical continuum flux. The results imply that the Fe II emission region is located somewhere between the radius corresponding to the Hβ lag and the outskirts of the broad line region (BLR).

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VARIABILITY OF AGNs IN THE CONTEXT OF THE MAIN SEQUENCE OF QUASARS

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Active galactic nuclei (AGN) are very luminous and variable sources. The optical luminosity, broad emission line shapes, and variability are parameterized along the main sequence (also known as eigenvector 1) of quasars. Here we present the variability measurements of emission line characteristics in the parameter space of eigenvector 1 (R_{FeII} vs. FWHM of Hβ). We used a sample of publicly available long-term monitoring spectra of AGNs belonging to different population types along the main sequence. Our preliminary results show that these objects vary mainly within the same types, and do not cross the boundary for structural changes between population A and B. We also noticed that in some cases, the R_{FeII} parameter varies differently with accretion rate than expected according to the main sequence predictions (the R_{FeII} decreases with the increment of the Eddington ratio). We propose that this effect could be due to the different response times and variation amplitudes of the Hβ and Fe II regions.

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NEBULAR SPECTROSCOPY OF THE ENIGMATIC SANDULEAK'S STAR IN THE LMC

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Sanduleak's star, a puzzling source in the Large Magellanic Cloud, has been tentatively classified as a symbiotic star based on its high-excitation nebular spectrum, but its unusual properties have left open the possibility that it is instead related to massive star evolution. The object, which was discovered in 1977, came back into the spotlight when we discovered that it powers a giant, highly-collimated bipolar jet extending over almost 15 pc, making it one of the largest stellar jets ever discovered and the first clearly resolved beyond the Milky Way. In this contribution we present our follow-up observations of Sanduleak's star obtained over the last few years. In particular we will present Magellan Telescope deep longslit spectroscopy of the jet and inner nebula. While the question of the real nature of the Sanduleak's star remains open, our findings underscore the importance of continued investigation into this intriguing object.

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PERIODIC VARIABILITY OF STRIPE 82 QUASAR LIGHT CURVES AND ASSOCIATED CHANGES IN Mg II EMISSION LINE PROFILES

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A search was conducted for long-period (100<P[days]<600) variability in the SDSS Stripe 82 region, resulting in the discovery of five spectroscopically confirmed quasars with periodic light curves. In order to better constrain the cause of the apparent optical periodicity (P=278 days) of our most likely periodic quasar candidate, we performed spectroscopic follow-up of Mg II emission line exhibiting a complex line profile. The results of the monitoring campaign are not disfavoring supermassive binary black hole scenario as an explanation of the cause of the variability.

The search utilized the precisely calibrated (1%-2%) Stripe 82 photometry in SDSS ugriz bands over approximately 6 years, and

Lomb-Scargle periodograms were used to identify the most likely candidates for periodically variable sources. These sources were then cross-matched with other surveys across the electromagnetic spectrum (photometry and spectroscopy) to confirm their variability and type. Time series data from Pan-STARRS and ZTF supported the analysis and extended the observational baseline to more than 20 years.

All the identified candidates were quasars, with the highest-ranked one flagged as a variable source in the Chandra X-ray catalogue. Various explanations for the observed periodic behavior of quasars include radio jet precession, tilted or warped accretion disks, tidal disruption events, and other accretion-related effects.

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FANTASTIC FITS OF AGN SPECTRA WITH FANTASY PYTHON CODE

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With the emerging spectroscopic surveys (e.g., SDSS-V, DESI, WEAVE, 4MOST, MSE, WST) there is a need to develop various open-source spectral analysis tools, which could be used either in a fast-mode for quick spectral analysis or in a slow-mode with detailed approach to access uncertainties of spectral fittings. We have recently released the software package `fantasy` (Fully Automated pythoN Tool for Agn Spectral analYsis), a tool for multicomponent fitting of active galactic nuclei (AGN) spectra in the optical and near infrared wavelength band. AGN spectra are modelled by simultaneously fitting the underlying broken power-law continuum, predefined emission line (narrow, broad, coronal, etc.) lists, and an Fe II model, which is here extended to cover the wavelength range from 3700 Å to 11000 Å.

Here we present a case study of the application of `fantasy` code on the sample of AGN taken from the SDSS survey, for which we show that when Fe II emission is present near Hβ, it is also detected redward from Hα, potentially contaminating the broad Hα line blue-wing. We show that the `fantasy` code works well when fitting AGN type 1 spectra from SDSS, but being open-source, flexible and easy to use, it shows good potential to be used for AGN spectral analysis in the coming spectral surveys.

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LONG-TERM MONITORING OF BROAD-LINE AGN

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Properties of the broad line region (BLR) in active galactic nuclei (AGN) are widely used to measure the mass of the supermassive black hole which powers an AGN. However, we still do not fully understand the kinematics and physical properties of the BLR, but we may use the optical variability to try to constrain them. On longer timescales (e.g., years/decades) the AGN spectra show expected stochastic variability, but it could vary substantially, e.g., the broad emission line can significantly change their flux, profiles or even completely disappear. The analysis of this dramatic change could help us in constraining and understanding the structure and physics of the BLR. Thus, it is essential to keep collecting both photometric and spectroscopic data of AGN on longer timescales.

Here we present the long-term monitoring campaign (LoTerm) of a sample of well-known broad-line AGN, which was initiated and run for decades by dr Alla I. Shapovalova, and continued through the LoTerm Collaboration, consisting from teams from the Special Astrophysical Observatory, Astronomical Station Vidojevica, Asiago Observatory, Mount Ekar Observing Station, Guillermo Haro Observatory, and Observatory Sierra Nevada. We will present the recent data on the well known extremely variable AGN, NGC 3516.

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3D STRUCTURE OF EXPANDING H II REGIONS

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Expanding H II and wind-blown bubbles are one of the main sources of the energy input in the interstellar medium along with supernova explosions. Depending on the energy, these expanding structures provide positive or negative feedback that controls the star formation process in surrounding molecular clouds. Observational verification of the feedback between expanding bubbles and the neutral surrounding material is relevant for the theory of star formation, since the sites of star formation - molecular filaments - are formed at the intersection of expanding shells around H II regions or wind-blown bubbles. We present a survey of H II regions and wind-blown bubbles on the northern sky with different structure and driven by stars of the whole range of O and B types.

The main aim of our study is to understand the relationship between the expanding bubbles and the morphology of surrounding molecular clouds, and reconstruct the 3D structure of the bubbles and surrounding neutral material. The study will be done using optical imaging with the Zeiss-1000 telescope and BTA-6m telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences (SAO RAS) and archival data in the infrared (IR). The IR data allow us to study the spatial distribution of neutral material around H II regions.

In this presentation, we discuss three star-forming complexes: S235 and S255-S257, where H II regions are excited by late O and early B-type stars. These H II regions demonstrate different types of morphology: from a 3D bubble surrounded by neutral material to blister-type. We determine their

electron densities, column density the the neutral hydrogen on the front and back walls and the depth along the line of sight. Combining the optical data with the far-IR [C II] and [O I] emission lines from the SOFIA flying telescope, we complement the 3D structure by the neutral gas kinematics. We show that the bubble-like structures appear substantially non-uniform and clumpy while they look like regular structures on the plane of the sky.

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OUTFLOW MORPHOLOGY IN THE ACTIVE GALACTIC NUCLEUS OF CIRCINUS GALAXY

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We present VLT/MUSE narrow-field mode observations of the Circinus galaxy at a spatial resolution of $\sim 0.1''$ (physical scale of ~ 2 pc) that resolve the central region of the AGN. The observations reveal a collimated ionized gas outflow fragmented into two filaments forming a 'tuning-fork' shape. While the origin of the collimated outflow could be a result of jet-ISM interactions on small scales, the extinction map obtained from the outflowing components suggests that the dust clump at the tip of the collimated part of the outflow might explain its fragmentation. We estimated a total instantaneous mass outflow rate of 10^{-2} $M_\odot$ yr^{-1} and a time-average mass outflow rate of 10^{-4} $M_\odot$ yr^{-1}.

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POLARIMETRIC REVERBERATION MAPPING OF AGNs IN MEDIUM-BAND FILTERS

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The classical reverberation method in type 1 AGNs makes it possible to measure the distance to rotating gas clouds around a supermassive black hole by estimating the time delay between the radiation flux in the broad emission line and the continuum. The extension of the classical method to polarized radiation in medium-band filters makes it possible to measure the distance to the equatorial scattering region, which, on the one hand, is difficult to measure by other methods, and, on the other hand, provides a more complete information about the unresolvable AGN central parsec and is useful for spectropolarimetric measurements of the masses of central SMBHs. We describe the observation technique and present the results of polarimetric monitoring of some studied AGNs.

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METAL CONTENT ALONG THE QUASAR MAIN SEQUENCE

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Gas outflows appear to be a phenomenon shared by the vast majority of type-1 active galactic nuclei. In this paper we review how the 4D eigenvector 1 scheme/main sequence helps to organize observed properties and to lead to meaningful constraints on the outflow physical and dynamical processes, with a special attention to the enrichment of the line emitting gas. The outflow phenomenology reaches its peak in the most luminous quasars that show a high prevalence of large blueshifts in the CIVλ 1549 and [OIII]$\lambda\lambda$ 4959,5007 emission line profiles. The ionized gas mass, kinetic power, and mechanical thrust are extremely high, and suggest widespread feedback effects on the host galaxies of very luminous quasars, at cosmic epochs between 2 and 6 Gyr from the Big Bang when they may have acted as a major factor in the chemical enrichment of the host galaxy.

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THE FESHBACH RESONANCES APPLIED TO THE CALCULATION OF STARK BROADENING OF IONZED SPECTRAL LINES: AN EXAMPLE OF INTERDISCIPLINARY RESEARCH

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Feshbach resonances take part in elastic collisional electron-ionized atom cross-sections. Z is the charge of the studied ionThese resonances are due to the fact that the colliding electron can be trapped on an excited state of the ion of charge Z - 1. This gives a temporary ion of charge Z - 1, and the trapped electron can be ejected by autoionization. These states form Rydberg series which converge towards the excited state of the ion of charge Z. Feshbach resonances were firstly applied to the calculation of elastic (and fine-structure cross-sections within a given term) electron-ion cross-sections in the sixties. In the beginning of seventies, the Feshbach resonances were applied to spectroscopic diagnostics in astrophysics, especially concerning the outer layers of the sun. The newly discovered X and XUV lines of ionized atoms were optically thin and formed out of LTE: many levels were coupled by electronic collisions and spontaneous emission. So, the "Statistical equilibrium equations" needed to be solved for obtaining their intensity. This idea permitted to understand and interpret the observations which remained in disagreement until then. It was also the case of the famous Fe XIV green line of the Corona. Then, as part of an interdisciplinary research, S. Sahal-Bréchot applied this idea to take into account the Feshbach resonances in the elastic contribution of electron collisions to Stark broadening of ionized lines in the impact approximation.

Within the framework of this interdisciplinary approach, and following Tsahal-Bréchot 2021, this work will be reviewed.

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INTRADAY VARIATIONS OF POLARIZATION VECTOR IN BLAZARS: A KEY TO THE OPTICAL JET STRUCTURE?

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For several decades, the optical variability of blazars has been actively investigated, which has given rise to a large number of existing long-term monitoring campaigns. However, recently there has been a special interest not in the long, but in the rapid variability of blazars (intraday variability), which is associated with the relativistic plasma motion in the unresolved jet region at scales <0.01 pc from the nucleus. It can be assumed that the study of this variability will help to study better the physical and kinematic processes in plasma and understand the nature of the flare activity of blazars. In this regard, the study of the rapid variations of the linear polarization vector, which are generated by the rotation of the emitting plasma in the jet magnetic field, helps to trace the trajectory of matter and the patterns of plasma motion. This report will present the results of optical polarimetric observations carried out by our team on the basis of 6m and 1m telescopes at SAO RAS: the study of the blazar S5 0716+714 radiation showed the presence of a period of the variability of brightness and a polarization vector variations on scales of 1.5 hours, constant on a long time scale; multi-colour monitoring of BL Lac polarization before, during and after the flare demonstrates the difference in the patterns of polarization vector variability depending on the wavelength, which can be considered as the influence of Faraday rotation; also, for a number of other blazars (3C 66A, 3C 454.3, S2 0109+224, etc.) in a quite not-in-flare state, it is shown the absence of signs of rotation of the polarization vector.

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REDUCING THE RUN TIME OF MCRT SIMULATIONS WITH HELP OF INLA

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Monte Carlo radiative transfer (MCRT) simulations have proven to be an important technique for comprehending the role of dust on astrophysical systems and its effects on observations. These simulations use a large number of photon packages to mimic the propagation of real photons in dusty environments, taking into account physical processes such as scattering, absorption, and thermal re-emission by dust grains. However, simulations of realistic 3D inhomogeneous dust distributions are computationally challenging.

We develop a novel technique for post-processing MCRT output capable to achieve the quality of high photon number images using computationally less expensive simulations of lower-quality images as an input. We combine principal component analysis (PCA) and non-negative matrix factorization (NMF) as dimensionality reduction techniques together with Gaussian Markov random fields and the integrated nested Laplace approximation (INLA), an approximate method for Bayesian inference, to detect and reconstruct the non-random spatial structure in the images of lower signal-to-noise ratios or with missing data.

We test our methodology using different MCRT images and show that with this approach we are able to reproduce high photon number reference images ~ 5 times faster with median residuals below $\sim 20\%$.

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DIFFERENTIAL INTERFEROMETRIC SIGNATURES OF CLOSE BINARIES OF SUPERMASSIVE BLACK HOLES IN ACTIVE GALACTIC NUCLEI

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Pairs of supermassive black holes (SMBHs) at different stages are the natural results of galaxy mergers in the hierarchical framework of galaxy formation and evolution. However, identification of close binaries of SMBHs (CB-SMBHs) with sub-parsec separations in observations are still elusive. Recently, unprecedented spatial resolutions achieved by GRAVITY/GRAVITY+ on board the Very Large Telescope Interferometer through spectroastrometry (SA) provide new opportunities to resolve CB-SMBHs. Differential phase curves of CB-SMBHs with two independent broad-line regions (BLRs) are found to have distinguished characteristic structures from a single BLR. Once the CB-SMBH evolves to the stage where BLRs merge to form a circumbinary BLR, it will hopefully be resolved by the pulsar timing array in the near future as sources of nanohertz gravitational waves. In this work, we use a parameterized model for circumbinary BLRs to calculate line profiles and differential phase curves for SA observations. We show that both profiles and phase curves exhibit asymmetries caused by the Doppler boosting effect of accretion disks around individual black holes, depending on the orbital parameters of the binary and geometries of the BLR. We also generate mock SA data using the model and then recover orbital parameters by fitting the mock data. Degeneracies between parameters contribute greatly to uncertainties of parameters but can be eased through joint analysis of multiple-epoch SA observations and reverberation mappings.

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MAGNETIC-FIELD DISTRIBUTION OF A WHITE DWARF

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A white-dwarf spectrum from the SDSS database (J124851.31-022924.73), covering the hydrogen Balmer series, is analyzed. The individual Balmer line shapes are significantly influenced by the Stark and Zeeman effects, allowing for inferring the plasma density and temperature, and the magnetic field in the WD atmosphere. It is established that no single set of the plasma parameters can satisfactorily explain the entire spectrum, strongly hinting at a rather wide distribution of the magnetic field magnitudes. A more refined modeling, accounting for the radiation-transport effects in the star atmosphere, is currently under way.

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STARK BROADENING MODELING WITH ML AND AI ALGORITHMS

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During past 20 years many Stark broadening models were developed that can calculate spectral lineshape and estimate a line width that is extensively used in plasma diagnostics of both astrophysical and laboratory plasmas. Some of these calculations yield results relatively fast, some of them need a lot of computational time. Therefore, idea of creating a machine learning (ML) model emerged as a tool for fast estimation of Stark width without need of huge computational time. In our approach, out of three tested models, random forest (RF) algorithm showed the best predictive power after it has been trained, where the coefficient of determination $R^2 = 0.94$ was obtained. Model was trained on a database created by merging parameters from Stark B and NIST atomic databases, it had 14 input parameters that were used to predict final Stark width. Results were compared with experimental ones as well as with SCP theory. We also checked for regularities in Stark effect, and they were also confirmed and in agreement with previous findings.

SHORT TALKS

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CALCULATIONS OF ENERGY LEVELS, OSCILLATOR STRENGTHS, TRANSITION PROBABILITIES AND LIFETIMES OF THE C-LIKE ION K XIV

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Energy levels, oscillator strengths, transition probabilities and lifetimes for the multicharged carbon like K XIV ion have been calculated with the configuration expansion: $2s^2\ 2p^2$, $2s^2\ 2p\ 3p$, $2s^2\ 2p\ 4p$, $2s^2\ 2p\ 4f$, $2s\ 2p^3$, $2s^2\ 2p\ 3s$, $2s^2\ 2p\ 4s$, $2s^2\ 2p\ 5s$, $2s^2\ 2p\ 3d$ and $2s^2\ 2p\ 4d$. Two methods were used in the calculations: the Hartree-Fock pseudo-relativistic approach using the Cowan atomic structure code and the Thomas-Fermi-Dirac-Amaldi potential approach using AUTOSTRUCTURE code. Results have been compared with available experimental data from NIST database. There is great lack on atomic structure data of K XIV and obtained new data will be important for plasma diagnostic and astrophysical modeling.

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ON THE QUASAR MAIN SEQUENCE AT HIGH REDSHIFT: AGN OUTFLOWS AND RADIOLOUDNESS RELATIONS

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Active Galactic Nuclei (AGN) outflows and winds in general seem to be an ubiquitous feature. Especially at high and intermediate redshift, many sources seem to harbour a powerful central mechanism that allows for strong jets in radio and/or winds observed in the optical and UV ranges of their spectra. Through the decomposition of the broad emission line profiles we are able to find some hint of the real relevance of winds for the structure and dynamics of the broad line emitting regions. Feedback contributions can be estimated through the decomposition of the broad emission line profiles from quasar spectra and high-ionisation lines such as C IVλ1549 and [O III]$\lambda\lambda$4959,5007. High-ionisation lines usually present a significant asymmetry towards the blue especially in radio-quiet sources that is strong evidence of outflow motions. At variance, radio-loud quasars tend to present modest blueshifted components and more symmetric profiles in both UV and optical ranges. In this work, we present a remarkable sample of 32 high-luminosity and high-redshift quasars ($z = 1.5\tilde{}3.7$) observed with ESO-VLT. Measurements are shown and contextualized taking advantage of a set of correlations associated with the quasar Main Sequence (MS), which consists of a parameter space that allows to connect observed UV, optical, and X-ray properties to the relative relevance of radiative and gravitational forces. We discuss the main differences found in accretion and feedback properties and highlight the effects of the radio-loudness on the emission line properties.

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ON THE STARK BROADENING OF Ga II SPECTRAL LINES

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Reliable data for Stark broadening of Ga II are important for abundance determination, stellar spectra analysis and synthesis, investigation of diffusion, calculation of absorption coefficient, and consequently equation of state, radiative acceleration and atmospheric stratification of gallium, which is overabundant in chemically peculiar stars (in particular Hg-Mn stars). These stars are mainly of A and late B type, where Stark broadening is the principal pressure broadening mechanism. Data on Stark broadening of Ga II are also of interest for white dwarfs.

In order to provide the needed Stark broadening data for Ga II spectral lines, we calculated, using the semiclassical perturbation theory (see Sahal-Bréchot et al. (2014) and references therein), Stark line widths and shifts determining line shapes for important Ga II lines. The calculations were performed for a grid of temperatures and densities of perturbing particles, for collisions with the most important charged constituents of stellar atmospheres, electrons, protons and He II ions. We used the obtained results for the investigation of the influence of Stark broadening on Ga II spectral lines in atmospheres of chemically peculiar stars of A type, with overabundance of gallium, and white dwarfs. The obtained data will be prepared also in VO (Virtual Observatory) and XSAMS (XML Schema for Atomic, Molecular and Solid Data) format for the implementation in

the international, on-line database STARK-B, a part of VAMDC (Virtual Atomic and Molecular Data Center).

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CONVOLUTION NEURAL NETWORK TO CHARACTERIZE THE VOIGT PROFILE OF THE LYMAN-ALPHA FOREST ABSORBERS

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Numerous cosmological studies including the equation of state of the Intergalactic medium (IGM) can be well studied using the Lyman-alpha (Lyα) forest. This work aims to develop a machine learning (ML) algorithm to analyze the absorption lines in the Lyα forest. This involves a two-part process: (i) a classification algorithm based on a Deep Neural Network to predict the number of Voigt profiles in a given section of the Lyα forest, and (ii) an ML algorithm based on a Convolutional Neural Network to predict the physical parameters of the Lyα absorption systems, such as Doppler width (b), H I column density (NH I), and absorption redshift. To achieve this, we have simulated the Voigt profiles and forward-modelled them to have similar properties to the real data such as adding realistic noise and convolving with the line spread functions of the Hubble space telescope (HST) spectrograph. This allows us to test the performance of our ML algorithms on real data. The technique recovers excellent estimates of NH I and b when tested on a held-back validation set. We tested the algorithms on the low-redshift quasar data observed from HST and compared the predicted values with values estimated using semi-automated codes and manual fitting. Our results demonstrate that ML can significantly increase the efficiency of analyzing the Lyα spectra and therefore improve the studies of the IGM.

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STUDYING SHOCK AND AMBIENT ISM PROPERTIES IN BALMER-DOMINATED SUPERNOVA REMNANTS

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Balmer-dominated shocks are mainly seen as faint edge-on optical filaments around young supernova remnants (SNRs). These shocks are non-radiative, collisionless and propagating through partially ionized interstellar medium (ISM). Among all hydrogen Balmer lines, Hα is the brightest with a characteristic two-component line profile. A narrow component with a width of $\sim 10\,\mathrm{km s^{-1}}$ is a result of pre-shock hydrogen atoms excited downstream of the shock and a broad component with a width of $\sim 1000\,\mathrm{km s^{-1}}$ is produced in charge-exchange reactions with the post-shock protons. These components are an important diagnostic tool for ISM and shock parameters: ambient density and neutral fraction, pre- and post-shock temperature, shock velocity, electron-to-proton temperature ratios upstream and downstream of the shock. Moreover, presence of shock precursors such as cosmic rays and neutral-induced precursor can alter Hα-line profile. We will show spectroscopic observations of Galactic SNRs SN 1006 and Tycho, and SNR 0509-67.5 in Large Magelanic Cloud.

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SPECTRAL LINE PROFILES AND MOLECULAR COMPLEXITY IN HOT CORES AROUND RCW 120

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Studying regions of massive star formation is a challenging problem due to their rarity and distance from observers. It is noteworthy that many complex organic molecules were first detected towards hot cores and hot corinos.

According to Herschel data, around 25 % of massive young stellar objects (MYSOs) are located in neutral envelopes of HII regions. The border of the expanding HII region RCW 120 contains several MYSOs, which represent the early stage of the hot core development. The simple morphology and relatively close distance from the Solar System (1.34 kpc) make this region suitable for observations with single-dish telescopes. However, to our knowledge, no attempts have been made to study molecular line emission towards the hot cores in the region.

Using the APEX telescope, we performed a spectral survey towards dense hot molecular cores in RCW 120. Our observations covered a broad range of frequencies, from 200 to 260 GHz. We detected 43 molecular line emissions, including isotopologues and deuterated species, towards the most massive hot core in the region. We reached a noise level of 14 mK, allowing us to investigate the profiles of molecular line emissions and thus to study kinematics in the vicinity of hot cores using molecular line emission of species such as SiO and CH_3OH, which are typically used to detect outflows. We also used position-velocity diagrams to study kinematics around the HII region. To determine physical conditions around MYSOs, we applied the rotational diagram method to different observed transitions of the CH_3CCH molecule.

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JOINT ANALYSIS OF THE IRON EMISSION IN THE OPTICAL AND NEAR-INFRARED SPECTRUM OF I ZW 1

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Constraining the physical conditions of the ionized media in the vicinity of an active supermassive black hole (SMBH) is crucial to understanding how these complex systems operate. Metal emission lines such as iron (Fe) are useful probes to trace the gaseous media's abundance, activity, and evolution in these accreting systems. Among these, the FeII emission has been the focus of many prior studies to investigate the energetics, kinematics, and composition of the broad-emission line region (BELR) from where these emission lines are produced. In this work, for the first time, we present the simultaneous FeII modeling in the optical and near-infrared (NIR) region. We use CLOUDY photoionization code to simulate both spectral regions in the wavelength interval 4000-12000 Å and analyze the results for the available FeII atomic datasets. We compare our model predictions with the observed line intensity ratios for I Zw 1 – a prototypical strong FeII-emitting Active Galactic Nuclei (AGN). This allows putting constraints on the BLR cloud density and metal content that is optimal for the production of the FeII emission by examining a broad parameter space. We will demonstrate the salient and distinct features of the FeII pseudo-continuum in the optical and NIR, and discuss the prominence of FeII emission in highly accreting sources.

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SYSTEMATIC ATOMIC STRUCTURE OF THE NEUTRAL COBALT ATOM (Co I)

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With the Hartree-Fock pseudo-relativistic and the Thomas-Fermi-Dirac--Amaldi potential approaches using the Cowan atomic structure and AUTOSTRUCTURE codes respectively, we calculated the atomic structure of the neutral cobalt atom (Co I). Comparison with available values are also presented.

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TRIPLE IONIZED MOLYBDENUM LINES IN THE SPECTRA OF THE DA-TYPE AND THE DO-TYPE WHITE DWARFS

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Molybdenum is trans-iron element and the most serious problem for the determination of these element abundances is the lack of atomic data. Investigations of the spectrum of the white dwarf RE 0503-289 indicate the presence of lines of multiply ionized elements such as Ga, Kr, Mo and Xe. Extreme overabundances of trans-iron elements are seen in DO white dwarfs, in a temperature range from 49500 K up to 70000 K.

In this context, we considered the lines of triply ionized molybdenum in the spectra of white dwarfs, especially of DA and DO type. Differences in the contributions of spectral line broadening for two different types of white dwarfs are due to different physical conditions, since effective temperatures and surface gravities are different .

More than ten 5s - 5p transitions of Mo IV of interest for the calculation of Stark broadening parameters, width and shift, were selected. A simple modified semi-empirical approach by Dimitrijević and Konjević, 1987 was applied. The obtained results may be particularly useful for determination of molybdenum abundances in white dwarfs and for laboratory plasma diagnostics.

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STUDY OF FAINT EMISSION SOURCES AND MASSIVE STARS IN IC 1613 GALAXY

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We present the study of low-brightness emission regions and feedback effect from massive stars in local dwarf irregular galaxy IC 1613. By using observations in Hα and [S II] narrow-band filters, as well as long-slit spectroscopy, we searched for new supernovae remnants and nebulae related to evolution of massive stars. Here we present obtained data for three diffuse shell-like, ionized nebulae located in the giant ($\sim$ 1 kpc) atomic HI gas supershell. Also, we consider the spectrophotometric properties of the known WR star candidates in this galaxy, using both our He II image and archival MUSE/VLT spectral data.

POSTERS

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Bajina Bašta, Serbia, June 19 - 23, 2023
Book of Abstracts, Eds. Luka Č. Popović, Nataša Bon, Edi Bon and Sylvie Sahal-Bréchot

APPLICATION OF STARK BROADENING OF Al IV SPECTRAL LINES IN ASTROPHYSICS

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The study is a continuation of our previous work on the Stark broadening width of Al IV spectral lines. Conditions of interest cover a wide range of temperatures, from 10 000 K to 160 000 K and electron density of 10^{17} cm^{-3}. The modified semiempirical method (MSE) is applied where the spectral lines are broadened by interactions of emitters with electrons. The studied spectral lines belong to the visible part of the spectrum which is of interest in both astrophysics research and laboratory plasma diagnostics. Temperature dependence of Stark width is analyzed. The similarities of Stark widths within multiplets and supermultiplets are discussed. Comparison with available experimental and calculated results from the literature is presented.

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ENIGMATIC EMISSION STRUCTURE AROUND THE NARROW-LINE SEYFERT 1 GALAXY MRK 783

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Mrk 783 is a narrow-line Seyfert 1 galaxy that possesses a relatively large two-sided radio emission extending up to 14 kpc from the active nucleus. The ionized gas emission spatially coinciding with the radio structure was recently detected. In this poster we present the tunable filter mapping of the Mrk 783 at the 2.5-m telescope of the Moscow State University. The image in the [O III] emission line reveals knots and filaments of the ionized gas possibly related not only to the radio structure, but also to tidal features illuminated by the active nucleus radiation. The [O III] filaments are observed up to projected distance 45 kpc from the nucleus. Using the spectroscopic observations at the Russian 6-m telescope we analyse the ionisation properties throughout the discovered gaseous structures and discuss their nature.

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STRONG DISTORTIONS OF LINE SHAPES IN PERIODIC ELECTRIC FIELDS

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Periodic electric fields are often found in plasmas due to the collective behaviour of the charged particles or the presence of an external source such as a radio frequency generator or a laser. In astrophysical and laboratory plasmas, the typical electrostatic oscillation frequency is the plasma frequency $\omega_p = \sqrt{Ne^2/(m\varepsilon_0)}$, where N, e and m are the density, charge and mass of the charged particle considered, and ε_0 is the permittivity of free space. We focus our interest on oscillations at the electronic plasma frequency since this rather high frequency has a signature on hydrogen line shapes for a large range of plasma conditions. Several decades of measurements and modelling have revealed the formation of structures near to the multiples of the plasma frequency [1,2]. We here assume that nonthermal effects amplify a Langmuir wave, whose electric field magnitude becomes larger than the average plasma microfield. We use a computer simulation of the ions retaining their motion, treat the electrons with an impact approximation, and we integrate the time-dependent Schrödinger equation for the quantum emitter retaining the simultaneous effect of the plasma microfield and the oscillating electric field. Our calculations show strong line shapes distortions as the magnitude of the oscillating field increases. We present results for the first Lyman and Balmer lines and we revisit early experimental Hβ line shapes [3] obtained in the presence of turbulent electric fields in a toroidal chamber.

References

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THE INTRINSIC REDDENING IN AGNs TYPE 1.9: INFLUENCE TO THE BLACK HOLE MASS ESTIMATION

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We used the sample of spectra of Active Galactic Nuclei (AGN) Type 1.9, taken from the Sloan Digital Sky Survey, to investigate the influence of the intrinsic reddening to the observed spectral properties. To estimate intrinsic reddening, we used the fluxes of the narrow Hα and Hβ lines, and standard extinction law given in Cardelli et al. (1989). The super-massive black hole masses (M_{BH}) are calculated using the properties of the broad Hα lines (their widths and luminosities) before and after correction for intrinsic reddening. We found that the intrinsic reddening has significant influence to the flux of AGNs Type 1.9, and it consequently affects the estimated M_{BH}s. The correction for intrinsic reddening slightly increases the correlation between M_{BH}s estimated using broad Hα line with stellar velocity dispersions.

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OPTICAL PROPERTIES OF TWO COMPLEMENTARY SAMPLES OF INTERMEDIATE SEYFERT GALAXIES

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We present preliminary results of the analysis of optical spectra of two complementary samples of Seyfert galaxies. The first sample was extracted from Foschini et al. (2022), which is composed of 50 gamma-ray emitting jetted Seyfert. The second one was extracted from the Swift/BAT AGN Spectroscopic Survey (BASS), which is composed of 144 hard-X ray selected AGN. The two samples are complementary since the former is expected to have small viewing angles, while the latter is characterized by objects with large viewing angles. We measured emission line ratios, profiles, equivalent width, and iron (Fe II) intensity. Our goal is to understand if intermediate Seyferts can be explained in terms of obscuration, as suggested by the well-known unified model of AGN, or if there are intrinsic differences due to the presence of jets and/or outflows.

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DATASET FOR ELECTRON-IMPACT PROCESSES INVOLVING HYDROGEN AND ALKALI MOLECULAR IONS

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The new data for electron-impact processes involving some small molecular ions have been reported. Collisional processes under consideration may have an effect on the atom excited-state populations i.e. Rydberg state populations, ionization level, and optical properties of various environments. Rate coefficients for electron-impact processes involving potassium, sodium, lithium and hydrogen molecular cations in domains of higher principal quantum numbers and temperatures up to 10 000 K are presented. The outcomes, i.e., the data gathered, could be used for various applications, such as plasma chemistry or experiments, for modelling atmospheres of diverse environments such as the interstellar medium, planets, and dwarf stars, and also in the plasma fusion area.

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THE INFLUENCE OF SOLAR X RAYS: MODELING ATMOSPHERE

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The atmosphere of the sunlit Earth is mostly influenced from outside by solar radiation, mainly in soft-range X-ray section of the electromagnetic spectrum. The ionosphere's photo-ionization rate is influenced by composite particles and the solar radiation spectrum at the altitude under consideration. Data on some solar spectral lines, especially as Lyman-alpha, and radiation could be very useful in studying solar flares. In this contribution we statistically analyzed the influence of solar flares i.e. radiation on Very Low Frequency VLF signals and atmosphere composition.

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MULTI-INSTRUMENTAL INVESTIGATION OF THE POWERFUL SOLAR FLARES IMPACT ON THE IONOSPHERE: CASE STUDY

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Case study of energetic solar events which included strongest solar flare of the previous solar cycle, X9.3 from 6 September 2017 and accompanying Coronal Mass Ejections (CMEs) directed towards Earth is presented through ionospheric and primary cosmic rays implications. Conducted analysis and numerical simulations were done both on data from ground-based Belgrade Very Low Frequency (VLF) and Cosmic Ray (CR) stations and space-borne satellite platforms of GOES and SOHO missions. Some of the main findings regarding related disturbances of ionospheric parameters and on primary cosmic rays are presented in this work.

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VISUALIZATION OF ADIABATIC DARK STATES UNDER TWO-PHOTON EXCITATION OF SODIUM ATOMS

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In our previous work [1], we theoretically analyzed the formation of three types of adiabatic states (dark, bright, and chameleon) in the Autler-Townes spectra of sodium atoms. Here we report on experimental identification of dark states in the spectra of sodium atoms under two-step laser excitation of a supersonic Na beam. In the experiment, a strong pump laser couples the hyper-fine components $F'' = 1, 2$ of the ground state $3s_{1/2}$ with components $F' = 1, 2$ of excited state $3p_{1/2}$ or $F' = 0, 1, 2, 3$ of $3p_{3/2}$ state. Populations and energies of the adiabatic (dressed) states are probed by scanning a comparatively weak laser field across the $3p_{1/2,3/2} \rightarrow 7d_{3/2}$ transitions. The corresponding excitation spectra reveal the presence of an intense peak with side-peaks of much smaller intensities. The side peaks experience a noticeable shift due to the Autler-Townes effect as the pump laser intensity is increased, while the position of the main peak remains virtually unchanged.

We interpret these experimental findings as the evidence of a "gray" state - a state of nearly constant Autler-Townes energy, that appears bright when the laser coupling is weak, but evolves into a proper dark state upon strong coupling [2].

References

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INITIAL STARK WIDTH INVESTIGATION OF Te II SPECTRAL LINES AND THEIR IMPORTANCE IN ASTROPHYSICAL APPLICATIONS

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Set of 39 spectral lines of Te II have been prepared for a purpose of pressure broadening parameter determination. For some of these lines, Stark widths were calculated using modified semiempirical (MSE) approach (Dimitrijević and Konjević, 1980). Line and multiplet factors were taken from Shore and Menzel (1965), while matrix elements were determined by using of oscillator strengths (Zhang et al, 2013) whenever it was possible similarly as it is done, for example, in the analysis of Stark broadening of Lu III (Majlinger et al, 2015). These results will be compared with the results obtained by classical use of Bates-Damgaard method within MSE formalism (Bates and Damgaard, 1949). Stark widths of Te II can be helpful in analysis of astrophysical spectra, where MSE method has been already used successfully in the previous researches concerning the Stark broadening calculations of spectral lines.

References

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A SPECTRAL ENERGY DISTRIBUTION FOR EXTREME POPULATION A SOURCES

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Knowledge of the broad-band active galactic nuclei (AGN) spectral energy distribution (SED) that ionizes the gas-rich broad emission line region (BLR) is key to understanding the various radiative processes at play and their importance that eventually leads to the emission lines formation. We modelled a set of SEDs for highly accreting quasars, also know as xA sources or extreme Population A, based mainly on observational data available at astronomical databases.

Our main selection criteria is the $R_{\rm Fe\,II}$ parameter, the ratio of the optical Fe II emission between 4434 Å and 4684 Å to the Hβ intensity, which yiels that high accreting sources (pop. A3 and A4) show $R_{\rm Fe\,II} \geq 1$. We started with over 300 xA sources previously reported on the literature and ended with nearly 50 xA sources used to create a set of mean SEDs spaning from radio to X-ray.

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THE CONNECTION BETWEEN THE BROAD EMISSION LINE PROPERTIES AND STELLAR VELOCITY DISPERSION IN SAMPLE OF AGNs TYPE 1

S. Marčeta Mandić[1], J. Kovačević-Dojčinović[1] and L. Č. Popović[1,2]

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Active galactic nuclei (AGN) is a compact region in an active galaxy with luminosity up to 10^4 times higher than the one of a typical galaxy. This luminosity excess is attributed to gas accretion into the super-massive black hole (SMBH) in the AGN centre. Several methods for estimating the super-massive black hole mass (M_{BH}) use AGN emission line spectral properties. Two of the most common are the single-epoch virial method, which uses the continuum luminosity and the width of the broad emission lines. The other is based on M_{BH}-stellar velocity dispersion (σ_*) relationship.

Here we investigate the accordance between these two methods for the sample of Type 1 AGN taken from the Sloan Digital Sky Survey (SDSS) for which stellar velocity dispersions are available in the literature. This was done by comparing correlations of SMBH masses estimated using the kinematical parameters of the broad Hα and Hβ emission lines, with the SMBH masses determined from the M_{BH}-σ_* relationship. Our results indicate that the shape of the broad emission lines may be affected by some non-gravitational kinematics and cause disagreement between these two methods.

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OPTICAL SPECTRAL VARIABILITY OF 12 BLAZARS

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From 2013 until 2019, we observed 47 active galactic nuclei (AGNs) which are candidate sources for the link between the International and Gaia Celestial Reference Frame. Observations were performed in optical V and R bands using eight telescopes from Serbia, Spain, Bulgaria, and Austria. We tested their brightness, colour, and spectral index variability. The optical spectral variability was tested with Abbe's criterion, and results are presented here.

Programme of 14th SCSLSA

Venue: Zepter Hotel "Drina", Bajina Bašta, Serbia

The time zone is CEST

Monday, June 19, 2023

16:00 -	*Arrival*
16:00 - 17:00	*Registration*
17:00 - 17:30	*Opening ceremony* *Nataša Bon ,Luka Č. Popović & Sylvie Sahal Bréchot*

DATABASES AND SPECTRAL LINE SHAPES FROM LABORATORY TO SPACE PLASMA

Chair: **S. Sahal-Bréchot**

17:30 - 18:00	***Branislav Marinković, Serbia***	Collisional databases within VAMDC: Synergy with COST Action RADAM
18:00 - 18:30	***Yuri Ralchenko, USA***	NIST Atomic Databases: data evaluation, uncertainties, online tools
18:30 - 21:30	*Welcome reception*	

Tuesday, June 20, 2023

SPECTRAL LINE SHAPES AND ASTROPHYSICAL PHENOMENA

Chair: **L. Č. Popović**

9:30 - 10:00	***Alexei Moiseev, Russia***	Radio jets and ionization cones in Seyfert galaxies
10:00 - 10:30	***Raj Prince, Poland***	Dissecting Mg II and Fe II emission lines in intermediate redshift quasars with SALT
10:30 - 11:00	***Patrice Theule, France***	Diagnostic emission lines in the Early Universe
11:00 - 11:30	*Coffee break*	

EMISSION LINES IN ACTIVE GALAXIES AND NEBULAE

Chair: **E. Stambulchik**

11:30 - 12:00	***Elena Shablovinskaya, Chile***	Optical spectropolarimetry of AGN: Insights on accretion disk, BLR and dust sublimation
12:00 - 12:30	***Djordje Savić, Belgium***	Probing the BLR geometry for quadruply lensed quasar Q2237+0305 with microlensing time series
12:30 - 12:50	*Eugene Malygin, Russia*	Polarimetric reverberation mapping of AGNs in medium-band filters
12:50 - 13:10	*Edi Bon, Serbia*	Optical reverberation mapping of the Fe II lines in NGC 4051
13:10 -13:30	*Francesco Di Mille, Chile*	Nebular Spectroscopy of the enigmatic Sanduleak's star in the LMC
13:30 - 15:00	*Lunch*	

SPECTRAL LINE PHENOMENA IN LABORATORY PLASMAS AND STARS

Chair: **M. S. Dimitrijević**

15:00 - 15:30	***Frank Rosmej, France***	X-Ray free electron laser driven resonance pumping of spectral lines of highly charged ions in dense plasmas
15:30 - 16:00	***Mohamed Kubiti, France***	Application of deep-learning to line spectra in magnetic fusion plasmas
16:00 - 16:20	*Evgeny Stambulchik, Israel*	Analysis of magnetic-field distribution of a white dwarf
16:20 - 16:40	*Sylvie Saha-Bréchot, France*	The Feshbach resonances applied to the calculation of Stark broadening of ionized spectral lines: An example of interdisciplinary research
16:40 - 16:55	*Abubaker Ahmed Siddig, Saudi Arabia*	Systematic atomic structure of the neutral cobalt atom (Co I)
16:55 - 17:10	*Lamia Abu El Maati, Egypt*	Calculations of energy levels, oscillator strengths, transition probabilities and lifetimes of the C-like ion K XIV
17:10 - 17:40	*Coffee break*	

POSTER SESSION: SPECTRAL LINES IN ASTROPHYSICAL AND LABORATORY PLASMA

Chair: **N. Bon**

17:40 - 18:40	*Poster session*	*3 min presentations*

Wednesday, June 21, 2023

SURVEYS AND SPECTRAL LINE VARIABILITY IN EXTRAGALACTIC OBJECTS

Chair: **D. Ilić**

9:30 - 10:00	***Maria Charisi, USA***	Multi-messenger searches for supermassive black hole binaries
10:00 - 10:30	***Marco Berton, Chile***	Exploring the jet-BLR connection: flare-induced variability in the optical emission lines
10:30- 10:50	*Nataša Bon, Serbia*	Variability of AGN in the context of the main sequence of quasars
10:50 - 11:10	*Paola Marziani, Italy*	Metal content along the quasar main sequence
11:10 - 11:30	*Yu-Yang Songsheng, China*	Resolving close binaries of supermassive black holes in the era of optical interferometry
12:00 -	*Conference excursion*	

Thursday, June 22, 2023

ATOMIC PARAMETERS AND SPECTRAL LINE SHAPES

Chair: **R. Stamm**

9:30 - 10:00	***Annette Calisti, France***	Study of the statistical and radiative properties of dense plasmas
10:00 - 10:30	***Nikola Cvetanović, Serbia***	Complex line shapes in non-thermal laboratory plasma
10:30 - 10:45	*Zoran Simić, Serbia*	Triply ionized Molybdenum lines in the spectra of the DA-type and the DO-type white dwarfs
10:45 - 11:00	*Milan S. Dimitrijević, Serbia*	On the Stark broadening of Ga II spectral lines
11:00 - 11:30	*Coffee break*	

SPECTRAL LINE PHENOMENA IN EXTRAGALACTIC OBJECTS

Chair: **A. Moiseev**

11:30 - 12:00	***Giustina Vietri, Italy***	Extremely high-velocity UV outflows in the most luminous QSOs at cosmic noon: discovery, implications & perspectives
12:00 - 12:30	***Konrad Tristram, Chile***	What the submm spectral line emission in the nucleus of the Circinus galaxy tells us about accretion and feedback in AGN
12:30 - 12:50	*Sladjana Knezevic, Serbia*	Outflow morphology in the active galactic nucleus of Circinus galaxy
12:50 - 13:10	*Majda Smole, Serbia*	Reducing the run time of MCRT simulations with help of INLA
13:10 - 13:30	*Maria S. Kirsanova, Russia*	3D structure of expanding HII regions
13:30 - 15:00	*Lunch break*	

SPECTRAL LINE PHENOMENA IN EXTRAGALCTIC OBJECTS

Chair: **E. Bon**

15:00 - 15:30	***Lovro Palaversa, Croatia***	Gaia as an AGN discovery machine
15:30 - 16:00	***Swayamtrupta Panda, Brazil***	Emission line regions in active galaxies: selected studies in spectral line variability in the era of JWST and LSST
16:00 - 16:20	*Marta Fatović, Croatia*	Periodic variability of Stripe 82 quasar light curves and associated changes in Mg II emission line profiles
16:20 - 16:40	*Elena Shablovinskaya, Chile*	Intraday variations of polarization vector in blazars: A key to the optical jet structure?
16:40 - 17:00	*Nemanja Rakić, R.Srpska, B&H*	Fantastic fits of AGN spectra with "fantasy"python code
17:00 - 17:30	*Coffee break*	

SPECTRAL LINE SHAPES IN DIFFERENT SPACE CONDITIONS

Chair: **S. Simic**

17:30 - 18:00	***Oleg Egorov, Germany***	Kinematics of the ionized gas in nearby galaxies as diagnostics of the energy balance between ISM and massive stars
18:00 - 18:15	*Karolina Plakitina, Russia*	Exploring the spectra and molecular complexity of hot cores in RCW 120
18:15 - 18:30	*Priyanka Jalan, Poland*	Convolution neural network to characterize the Voigt profile of the Lyman-alpha forest absorbers
18:30 - 18:45	*Milica Vučetić, Serbia*	Study of faint emission sources and massive stars in IC1613 galaxy
18:45 - 19:00	*Sladjana Knežević, Serbia*	Studying shock and ambient ISM properties in Balmer-dominated supernova remnants
20:00 -	*Conference Dinner*	

Friday, June 23, 2023

SPECTRAL LINE RESEARCH: NEW FRONTIERS

Chair: **V. Srecković**

09:30 - 10:00	***Ibtissem Hannachi, France***	Computer simulations of the effect of oscillating electric fields on line shapes
10:00 - 10:20	*Ivan Traparić, Serbia*	Stark broadening modeling with ML and AI algorithms
10:20 - 10:50	*Coffee break*	

SPECTRAL LINE VARIABILITY AND OTHER CHARACTERISTICS IN AGNs

Chair: **P. Marziani**

10:50 - 11:20	***Predrag Jovanović, Serbia***	Optical and X-ray counterpart of subparsec supermassive binary black holes
11:20 - 11:40	*Dragana Ilić, Serbia*	Long-term monitoring of broad-line AGN
11:40 - 11:55	*Alice Deconto-Machado, Spain*	On the quasar Main Sequence at high redshift: AGN outflows and radioloudness relations
11:55 - 12:10	*Denimara Dias dos Santos, Brazil*	Joint analysis of the iron emission in the optical and near-infrared spectrum of I Zw 1

12:10 - 12:30	*Official closing of the conference*
12:30 - 14:00	*Lunch break*
14:15	*Departure*

POSTERS

P01	*Magdalena Christova & Milan S. Dimitrijević*	Application of Stark broadening of Al IV spectral lines in astrophysics
P02	*Aleksandrina Smirnova*	Enigmatic emission structure around the narrow-line Seyfert 1 galaxy Mrk 783
P03	*Roland Stamm, Ibtisem Hannachi , J. Rosato, Y. Marandet*	Strong distortions of line shapes in periodic electric fields
P04	*Jelena Kovačević-Dojčinović, Ivan Dojčinović, Luka Č. Popović*	The intrinsic reddening in AGNs Type 1.9: influence to the black hole mass estimation
P05	*Benedetta Della Barba et al.*	Optical properties of two complementary samples of intermediate Seyfert galaxies
P06	*Vladimir . A. Srecković, S. Tošić and V. Vujčić*	Dataset for electron-impact processes involving hydrogen and alkali molecular ions
P07	*Kolarski, A., Srecković V. and Mijić Z.*	The influene of Solar X-rays: modeling atmosphere
P08	*Kolarski, A., Veselinović, N., Srecković, V. A., Mijic, Z., Savić M. and Dragić A.*	Multi instrumental investigation of the powerful solar flares impact on the ionosphere: case study
P09	*Arturs Cinins, Milan S. Dimitrijević, Vladimir A. Srecković, Martins Bruvelis, Kaspars Miculis, Nikolai N. Bezuglov and Aigars Ekers*	Visualization of adiabatic dark states under two-photon excitation of sodium atoms
P10	*Zlatko Majlinger, Milan S. Dimitrijević, Vladimir Srecković*	Initial Stark width investigation of Te II spectral lines and their importance in astrophysical applications
P11	*Karla Garnica Luna, D. Dultzin, P. Marziani, S. Panda*	A spectral energy distribution for extreme population A sources
P12	*Sladjana Marčeta-Mandić, Jelena Kovačević-Dojčinović, Luka Č. Popović*	The Connection Between the Broad Emission Line Properties and Stellar Velocity Dispersion in Sample of AGNs Type 1
P13,	*Miljana Jovanović, Goran Damljanović*	Optical Spectral Variability of 12 Blazars

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