
# IX Serbian Conference on Spectral Line Shapes in Astrophysics

# BOOK OF ABSTRACTS

Eds. Luka Č. Popović, Milan S. Dimitrijević, Zoran Simić and Marko Stalevski


Astronomical Observatory

Belgrade, 2013

**IX SERBIAN CONFERENCE ON SPECTRAL LINE SHAPES IN ASTROPHYSICS**

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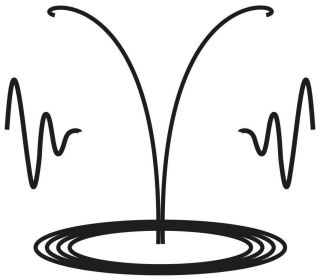


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# SOME NEW IDEAS TO STUDY THE COMPLEX BAL PROFILES IN THE SPECTRA OF AGNs

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It is known that in BALQSOs spectra we can detect many absorption lines (like C IV, Si IV) presenting very broad and complex profiles. An idea to explain these profiles is that the dynamical systems of Broad Line Regions are not homogeneous but consist of a number of dense clouds with different physical parameters. A general problem in the study of the origin of these clouds is that there was no solution of the radiative transfer equation through such a complex environment in order to calculate the physical parameters for each one of the clouds such as the radial and rotational velocities, the random motions of the ions, the Full Width at Half Maximum of the considered spectral lines, the optical depth, the corresponding absorption and emission energy for each one of the clouds etc. In this paper we present a new model able to study the complex BAL profiles in the spectra of AGNs and to calculate the physical parameters' values of each one of the AGN clouds that contribute to the construction of the complex BAL profiles in the AGN spectra.

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# USING AGN BROAD EMISSION LINES TO MEASURE BLACK HOLE MASSES

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The gas responsible for emitting the characteristic broad emission lines observed in AGN spectra is photoionized by high-energy continuum photons emitted by the thermal accretion disk surrounding the black hole. The consequence is that changes are observed in the integrated line flux that mirror changes seen in the continuum flux, but after a time delay that corresponds to the mean light travel time between the central continuum source and this broad line-emitting gas in the "broad line region" (BLR). Measuring this time delay, or lag $\tau$, between flux variations in the AGN continuum and broad emission-line light curves provides a measure of the BLR radius, $R_{\rm BLR} = c\tau$. This technique, known as reverberation mapping is used to measure the mass of the central black hole, but it is time and resource intensive. Luckily, $R_{\rm BLR}$ measurements made for $\sim$50 local AGNs provide means for estimating a black hole mass from the single epoch spectrum. This makes it possible to estimate black hole masses for large samples of objects across the observable universe. I will demonstrate how we use broad emission lines and reverberation mapping to measure black hole masses both directly and indirectly from single-epoch spectra. I will then discuss recent work that has uncovered the source of the systematic problems that exist for black hole masses based on the C IV $\lambda$1549 line, the emission line most applicable for studying black holes in the high-redshift universe. Finally, I show ways that these problems can be mitigated to produce reliable black hole mass estimates based on C IV. This work has significant implications for our understanding of black hole growth and the co-evolution of black holes and galaxies, as this evolution can be more precisely probed with better constraints on the observed black hole mass distributions at all redshifts.

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# RADIATIVE TRANSITIONS IN FEW ELECTRON QUASYMOLECULES

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Calculations of spectral profiles produced by atom/ion collisions need some preliminary quantum chemical information such as potential energy surfaces, dipole transition moments, etc. The main advantage of few electron systems is that all input data can be obtained *ab initio* or analytically thus the profiles calculated do not include any fit parameters. It is supposed to discuss two specific examples. The first one deals with radiative transitions produced by charge exchange in collisions of $He^+(n=3)+H^+ \rightarrow He^{2+}+H(n=1)$. The second example concerns radiative transitions produced by the $H+H^-$ collisions. For both cases the profiles as well as the total cross sections of the processes have been calculated.

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# PUTTING TOGETHER LINE AND CONTINUUM OBSERVATIONS OF THERMAL ACTIVE GALACTIC NUCLEI: A UNIFIED PICTURE OF THE ACCRETION DISC AND BROAD-LINE REGION

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I will demonstrate that the radial structure of the accretion disc in thermal active galactic nuclei (AGNs) is well constrained by observations of the UV?optical spectral energy distribution. The observed optical flux therefore gives the scale of the accretion disc.

The scale factor is consistent with the outer edge of the disc being the dust sublimation radius measured by near IR reverberation mapping.

Since reverberation mapping observations also show that the dust sublimation radius is the outer edge of the broad-line region (BLR), the accretion disc and the BLR must occupy the same radius. All observations of the BLR are consistent with it being a turbulent disc.

The covering factor and vertical component of velocity are well constrained. Observations of continuum and line variability require continuum variations in thermal AGNs to be highly non-axisymmetric. A unified picture of the accretion disc and BLR is sketched where a significant fraction of the gravitational potential energy released by accretion is stored in the magnetic field and released in magnetic reconnection events. These produce the observed, strong, off-axis flares, expel broad-absorption-line clouds, and provide the particle acceleration needed for the corona. Furthermore, magnetic loops offer the possibility of explaining the confinement, vertical velocities, height, filling factor, and survival of the broad-line region.

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# RADIATION HYDRODYNAMICAL SIMULATIONS OF CEPHEIDS

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Cepheids are an important part of the cosmic distance ladder. With the advent of new, extremely large optical telescopes such as the E-ELT on the one hand and precision astrometry from space with GAIA on the other a more detailed knowledge of their physics beyond the classical results has become important even beyond the fields of stellar astrophysics and hydrodynamics themselves. To explain double-mode pulsation and the red-edge of the classical instability strip and their dependence on metallicity without resorting to adjustable parameters that appear in simplified models of convection appears highly desirable. A detailed study of the convection-pulsation interaction based on numerical radiation hydrodynamical simulations provides an alternative to traditional, one-dimensional models with their high number of up to eight free parameters. Other interesting questions which can be studied with such simulations are related to the photospheric dynamics of Cepheids characterized by strong shock fronts and a net mass outflow. An analysis of such features may also help to reduce systematic errors introduced in parameter determinations of Cepheids which are still largely based on classical, hydrostatic model atmospheres. In this talk results from such a study of the convection-pulsation interaction in Cepheids and of the dynamical properties of their photosphere are reported. To this end the ANTARES hydrodynamical simulation code has been developed which can tackle the difficult numerical challenges underlying such simulations. These challenges and methods how to deal with them are briefly reviewed before simulation results and results from a first analysis of a short period Cepheid are presented.

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## QUASARS AND THEIR EMISSION LINES AS COSMOLOGICAL PROBES

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Quasars are the most luminous stable sources in the Universe. Unfortunately quasars also cover an impressive range of luminosities and therefore cannot be considered "standard candles" by any mean. Yet emission line properties can yield estimates of each quasar's central black hole mass and accretion rate. We discuss several methods that can potentially exploit quasars' physical properties to obtain useful constraints on the main cosmological parameters. We stress that a realistic application of methods based on broad emission lines would benefit of a better understanding of the line emitting region structure.

## ANALYZING RESOLVED EMISSION LINES: AN INSTRUMENT TO STUDY STARBURST AT DIFFERENT z

**C. Muñoz-Tuñón et al.**

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Line profile analysis is frequently used as the tool to search for the ISM kinematics. Emission line widths together with the luminosity are the parameters used in the scale relations, which relate star forming regions, from Giant HII regions to HII galaxies, in the local Universe. The scale relations are starting to be used also for the starburst galaxies in the high-z Universe and, therefore, to be able to sample the line profiles is more important now than ever. I will discuss some examples of the results that can be achieved by means of resolved emission lines in starburst. I will show also that the high-resolution spectroscopy of emission lines provides an extremely useful tool not only to determine the star formation feedback but also to unveil structures not resolved in the images.

# THE RADIO LINES OF HYDROGEN

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It was first suggested by Kardashev [1], that it should be possible to detect radio recombination lines in HII regions and Griem [2] and Peach [3, 4] used the impact theory of line broadening to estimate line widths. Various problems have arisen over the years in comparisons between theory and observation and have been attributed to numerous causes such as detection techniques and the use of uniform density models of the nebulae. Observations of the radio lines and their analysis have subsequently been greatly refined, see Bell [5] for a detailed discussion of these developments. It has now become clear that there are discrepancies between theory and observation that have not been satisfactorily explained, see Griem [6] and Gordon and Sorochenko [7].

It is therefore desirable that the theoretical approach to the line broadening problem should be reexamined, and new calculations carried out. Results will be presented at the conference.

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# ARE BOLTZMANN PLOTS OF HYDROGEN BALMER LINES A TOOL FOR IDENTIFYING A SUBCLASS OF S1 AGN?

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It is becoming clear that we can define two different types of nearby AGN belonging to the Seyfert-1 class (S1), on the basis of the match or less of the intensities of their Broad Balmer Lines (BBL) with the Boltzmann Plots (BP). These two types of S1 galaxies, that we call BP-S1 and noBP-S1 galaxies are characterized in first approximation by Broad Line Regions (BLR) which bear quite different structural and physical properties. We show in this communication that these features can be well pointed out by a multiwavelength analysis of the continuum and of the broad recombination Hydrogen lines. The investigation is addressed to verify whether BP-S1 are the ideal candidates for the study of the kinematical and structural properties of the BLR, for a reliable guess of the mass of their central engine and for the observation of their nuclear continuum spectrum.

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# HIGH RESOLUTION SPECTROSCOPY IN THE UV DOMAIN

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Ultraviolet spectroscopy has a significant impact on studies of the physical characteristics of planets, stars, galaxies and interstellar and intergalactic matter. The UV domain is of special interest for astronomers since it is here that we find the resonance lines of the most abundant atoms and ions in plasmas with temperatures between 3000 K and 300,000 K as well as the most abundant molecules – $H_2$, $CO$, $OHCS$, $S_2$, $CO_2^+$, $C_2$, and many others. The UV range is not accessible from the ground. Progress in the field therefore depends upon development of space-based instrumentation. The number of short term experiments and long term observatories designed for observation in UV domain exceeds 60. The most powerful observatory ever flown, the *Hubble Space Telescope* is expected to operate till 2016-2017. In late 2016 the *World Space Observatory - Ultraviolet* mission will be flown. This will guarantee access to the UV Universe for the next decade. Some amazing scientific results are presented in this lecture as well as instrumentation limitation for UV observations and challenges that UV missions meet.

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# STARK-B DATABASE AS A RESOURCE FOR "STARK" WIDTHS AND SHIFTS DATA: STATE OF ADVANCEMENT AND PROGRAM OF DEVELOPMENT

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"Stark" broadening theories and calculations have been extensively developed for about 50 years and can now be applied to many needs, especially for accurate spectroscopic diagnostics and modelling. This requires the knowledge of numerous collisional line profiles. Nowadays, the access to such data via an on line database becomes essential. STARK-B [1] is a collaborative project between the Astronomical Observatory of Belgrade and the Laboratoire d'Étude du Rayonnement et de la matière en Astrophysique (LERMA). It is a database of calculated widths and shifts of isolated lines of atoms and ions due to electron and ion collisions (impacts). It is devoted to modelling and spectroscopic diagnostics of stellar atmospheres and envelopes, laboratory plasmas, laser equipments and technological plasmas. Hence, the domain of temperatures and densities covered by the tables is wide and depends on the ionization degree of the considered ion. STARK-B has been fully opened since September 2008 and is in free access. The first stage of development was ended in autumn 2012, since all the existing data calculated with the impact semiclassical-perturbation method and code by Sahal-Bréchot, Dimitrijević and coworkers have now been implemented. We are now beginning the second stage of the development of STARK-B. The state of advancement of the database and our program of development will be presented at the conference, together with its context within VAMDC [2]. VAMDC is an international consortium which has built a secure, documented, flexible interoperable platform e-science permitting an automated exchange of atomic and molecular data.

## References

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[2] http://www.vamdc.eu/

# NEW LIGHTS ON THE STRUCTURE OF THE BROAD LINE REGION WITH QUASAR MICROLENSING

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Our detailed understanding of the working engine of AGNs is still incomplete. Several basic questions remain such as: What is the geometry and kinematics of the gas flow near the black hole? How do the size of the broad line region (BLR) change as a function of the ionisation degree of the line and of the AGN's properties? Are the characteristics of the BLR changing with cosmic time? The answer to these questions is still elusive, mainly because the inner regions of the AGNs remain unresolved with current telescopes. However, nature provides us with gravitational lens telescopes which help us in our understanding of AGNs: Multiply imaged lensed AGNs, which are observed when a massive galaxy lies on our line-of-sight to a distant AGN. In those systems, the stars in the lensing galaxy magnify regions of the lensed AGN as small as a few micro-arcsecs. This scale coincides with the size of the region where most of the AGN emission comes from. In this talk, I will show that it is possible to use this so-called microlensing effect as a tool to probe the AGN structure at redshift $z > 0.5$. I will give an overview of observational evidences for microlensing-induced emission line deformations in type 1 and broad absorption line quasars. I will explain how this signal can be used to to estimate the size of the BLR. The constraints provided by the microlensing signal on the geometry of the BLR and on the geometry the outflowing absorbing material in BALs will also be discussed.

# REVIEW OF THE FIRST SLSP CODE COMPARISON WORKSHOP

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Line-shape analysis is one of the most important tools for diagnostics of both laboratory and space plasmas [1]. Evidently, its reliable implementation requires sufficiently accurate calculations. The Stark broadening is the most computationally challenging contribution, with other factors (such as the Zeeman and Doppler effects) further complicating the calculations. Therefore, except for limiting cases, line-shape calculations imply a usage of computer codes of varying complexity and requirements of computational resources. There exist several such codes and, necessarily, limits of applicability, accuracy, and in the end, results, differ from one to another. However, studies comparing different computational and analytical methods are almost nonexistent. The 1st Spectral Line Shapes in Plasma (SLSP) code comparison workshop [2] intended to fill this gap. The organization of the meeting was modeled after the very successful series of NLTE workshops running since mid 1990's [3] (and which in turn were inspired by the Opacity Workshops, initiated in the late 1980's [4]), where a detailed comparison of results for a preselected set of standardized case problems was carried out and analyzed.

In this talk, a general review of the SLSP workshop will be presented, focusing on motivation for the case problems chosen, and followed by discussion of selected results.

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# LINE SHAPES AND INTENSITIES IN FLUCTUATING PLASMAS

**R. Stamm, R. Hammami, H. Capes, L. Godbert-Mouret, M. Koubiti, Y. Marandet, J. Rosato**

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Line shapes and intensities of atoms and ions in a plasma may be affected by plasma fluctuations. We want to describe the effect on radiative properties of equilibrium and out of equilibrium plasma fluctuations with a unique formalism. For this purpose, we model the fluctuating variables by a stepwise constant stochastic process obeying to a prescribed probability density function (PDF). The time durations on each step are sampled along a waiting time distribution (WTD). For Stark line shapes in equilibrium plasmas, the Model Microfield Method (Frisch and Brissaud, JQSRT 11, 1753(1971)) provides a simple model using an exponential WTD. This model may be extended to other stochastic processes, as long as stationarity conditions are satisfied. We compare Lyman alpha profiles obtained with exponential, Gaussian and Weibull WTD for a wide range of plasma densities. Atomic populations may also be changed in presence of turbulent fluctuations of the plasma density or temperature. Gamma function PDF for the density or temperature are sometimes measured in a turbulent plasma. Assuming an exponential WTD we have studied the behaviour of the atomic population of simple systems as a function of the typical turbulent frequency.

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# COMPARING H$\beta$ AND MgII 2798 AS VIRIAL ESTIMATORS OF BLACK HOLE MASS IN QUASARS

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The broad MgII2798 and H$\beta$ lines are the most reliable virial estimators of black hole mass in quasars. Which is more reliable? Part of the challenge centers on comparing MgII and H$\beta$ line profiles in order to improve the $\pm$ 1-2 dex $M_{BH}$ uncertainties inherent in single-epoch FWHM measures from noisy spectra. Comparison of MgII and H$\beta$ FWHM measures in the same sources provide an ideal way to compare the two lines. We identified 680 bright SDSS DR8 quasars with spectra showing both MgII and H$\beta$ (z=0.4-0.75). The S/N of these spectra are high enough to allow binning in the 4D Eigenvector 1 optical plane. High S/N median composite spectra were computed for 8 distinct bins. Resultant composite spectra yield essentialy rms FWHM measures in a restricted range of quasar luminosity (median $\log L \sim 46.2 \pm 0.2$). We confirm that FWHM MgII shows a profile $\sim 20\%$ narrower than H$\beta$. MgII apparently arises at a larger distance from the ionizing continuum. Further refinement requires distinction between sources with narrower Population A and broader Population B profiles. Population A sources show both H$\beta$ and MgII profiles best-fit with Lorentz functions. FWHM MgII measures based on Gaussian profile fits will yield $\log M_{BH}$ estimates 0.1-0.2 dex too high. Spectral type A1 and A2 conform to the general trend of narrower FWHM MgII while extreme Pop. A bins show an increasing ratio FWHM(MgII)/FWHM(H$\beta$) along with a significant MgII profile blueshift which is likely the signature of a radiation-driven wind. FWHM measures for Population B sources are less certain because they show more complex profiles involving at least two broad-line components involving an nearly unshifted broad (BC) and redshifted very-broad (VBC) components. Only the BC is likely to be a valid virial estimator. If H$\beta$ and MgII are not corrected for the VBC then $M_{BH}$ values for Pop. B sources will be systematically overestimated by $\log M_{BH} \sim 0.3 - 0.4$. We suggest a simple correction that can be applied to the majority of sources. MgII is the safer virial estimator for Pop. B sources because the centroid shift at half maximum is less than for H$\beta$. In the BC+VBC interpretation this is a consequence of the lower VBC/BC ratio in MgII.

## PROBING THE CONNECTION BETWEEN BLACK HOLES AND GALAXIES

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The correlation of central black hole masses ($M_{BH}$) with the properties of their host galaxies indicates a fundamental connection between black hole growth and the history of galaxy assembly. To investigate the origin of the correlation, it is important to reliably determine black hole masses and investigate cosmic evolution of the black hole-galaxy correlations. In this talk, I will review 1) the recent developements of the $M_{BH}$- stellar velocity dispersion ($\sigma_*$) relation of quiescent and active galaxies, based on the kinematic measurements from spatially resolved spectra, probing whether quiescent and active galaxies have different $M_{BH}$-$\sigma_*$ relation; 2) the recent efforts to determine black hole masses based on reverberation mapping results and single-epoch spectra; and 3) cosmic evolution of the correlations between $M_{BH}$ and host galaxy properties, based on the local calibration of single-epoch mass estimates and the local $M_{BH}$-$\sigma_*$ relation.

## ON THE ROLE OF DENSITY AND EDDINGTON RATIO IN THE CORRELATION SPACE OF NLS1 GALAXIES

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Narrow-line Seyfert 1 (NLS1) galaxies are an important sub-class of active galactic nuclei, characterized by extreme and remarkable properties. We have carried out an analysis of the correlation space of NLS1 galaxies, in comparison to broad-line Seyfert 1 galaxies. Our main focus was to identify the underlying drivers of their exceptional emission-line and continuum properties. We have done a principal component analysis. We find that the density of the narrow-line region is a significant parameter of the Eigenvector 1 space of our sample, as important as the Eddington ratio. A major implication of our findings is a close link between the properties of the central engine and the host galaxy.

*Progress reports*

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# A STATISTICAL STUDY OF C IV REGIONS IN 20 Oe - TYPE STARS

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In this paper, using the GR model, we analyze the UV C IV resonance lines in the spectra of 20 Oe stars of different spectral subtypes, in order to detect the structure of C IV region. We study the presence and behavior of absorption clouds and analyze their characteristics. From this analysis we can calculate the values of a group of physical parameters, such as the apparent rotational and radial velocities, the random velocities of the thermal motions of the ions, the Full Width at Half Maximum (FWHM), the optical depth, as well as the absorbed energy and the column density of the independent regions of matter which produce the main and the satellites clouds of the studied spectral lines. Finally, we present the relations between these physical parameters and the spectral subtypes of the studied stars and we give our results about the structure of the C IV region in their atmosphere.

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# ELECTRON DENSITY MEASUREMENTS OF SOLAR FLARE PLASMAS USING LINE RATIO TECHNIQUES

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Using high-resolution and high-quality spectra observed by nowadays satellites, data covering a very large wavelength range is now possible.

Solar flares are considered as increases in the luminosity of the Sun due to changes in the temperature and density of the coronal plasma.

Line intensity and widths and shifts and profiles of spectral lines are good tools for diagnostic studies.

Accurate atomic data are required to interpret the UV and X-ray spectra of solar flare plasmas. Precise atomic data and computations are necessary in diagnosing solar plasma and understanding their structure.

Line intensities ratio show strong dependence on the electron temperature and density in plasmas.

Atomic data needed to compute line intensities are energy levels, radiative transition probabilities and collision strengths. We used in this work the top of art data to estimate the electron density of solar flares.

The theoretical intensity ratios have been calculated using the statistical equilibrium code of Dufton (Comp. Phys. Comm., **13**, 25, 1977) and the line intensity ratios have been fitted using a formula by Feldman et al. (Astrophys. J., **679**, 843, 2008).

# ANOMALIES IN RADIATION-COLLISIONAL KINETICS OF RYDBERG ATOMS INDUCED BY THE EFFECTS OF DYNAMICAL CHAOS AND THE DOUBLE STARK RESONANCE

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Radiative and collisional constants of excited atoms contain the matrix elements of the dipole transitions and when they are blocked one can expect occurring a number of interesting phenomena in radiation-collisional kinetics. In recent astrophysical studies of IR emission spectra it was revealed a gap in the radiation emitted by Rydberg atoms (RA) with values of the principal quantum number of $n \approx 10$ [1]. Under the presence of external electric fields a rearrangement of RA emission spectra is possible to associate with manifestations of the Stark effect. The threshold for electric field ionization of RA is $E \approx 3 \bullet 10^4$ V/cm for states with $n > 10$. This means that the emission of RA with $n \geq 10$ is effectively blocked for such fields. In the region of lower electric field intensities the double Stark resonance (or Förster resonance) becomes a key player. It turns out [2] that the static magnetic or electric fields may strongly affect the radiative constants of optical transitions in the vicinity of the Föster resonance resulting, for instance, in an order of magnitude reduction of some lines intensity.

In the atmospheres of celestial objects lifetimes of comparatively long-lived RA states and intensities of corresponding radiative transitions can be associated with the effects of dynamic chaos via collisional ionization. The Föster resonance allows to manipulate the random walk of RE in the manifold of quantum levels [2] having redistributed, thus, the excitation energy of RA with occurrence of accompanying anomalies in the IK spectra.

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# ROLE OF THE COLLISIONS IN THE RADIATION REDISTRIBUTION: POLARIZATION FAR WINGS OF LINES FORMED BY SCATTERING

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This work is intended to the interpretation of the so-called "Second Solar Spectrum" (Stenflo, 1996), which is the spectrum of the linear polarization formed by scattering and observed close to the solar limb, but on the disk. The lines are also optically thick, and the problem is to solve in a coherent manner, the statistical equilibrium of the atomic density matrix and the radiative transfer in the atmosphere. Following Belluzzi & Landi Degl'Innocenti (2009), 30 % of the solar visible line linear polarization profiles display the M-type shape typical of coherent scattering effect in the far wings. A new theory including both coherent and resonant scatterings was developed by Bommier (1997a,b). In this theory, which is straightly derived from the Schrödinger equation for the atomic density matrix, the radiative line broadening appears as a non-Markovian process of atom-photon interaction. The collisional broadening is included. The published formalism was limited to the two-level atom without lower level alignment. But most of the solar lines are more complex. We will present how the theory has to be complemented to be enabled for multi-level atom modeling, including lower level alignment. The role of the collisions as balancing coherent and resonant scatterings is fully taken into account. Progress report will be given about the development of a new code for the numerical iterative solution of the statistical equilibrium and radiative transfer equations, for multi-level atoms.

## SPECTROSCOPIC DETECTION OF SUPERMASSIVE BINARY BLACK HOLE SYSTEMS IN AGN

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The variability of emission line shapes and fluxes in active galactic nuclei (AGNs) might be caused by supermassive binary black hole (SMBBH) systems in their cores. Using a method similar to those typically applied for spectroscopic binary stars it might be possible to obtained radial velocity curves of the supermassive binary system, from which could be calculated orbital elements and masses of components. Recent observational evidences of spectroscopically resolved supermassive sub-parsec orbits in the core of Seyfert galaxies opens many questions for understanding AGN and the mechanisms responsible for the production of such a large energies in cores. If black hole mass grows via major mergers, then we might expect to see the signature of a binary BH in some or many active galaxies. Here we present spectroscopic study of several SBBH candidates.

## DIFFERENCES OF THE STELLAR POPULATION BETWEEN THE HII GALAXIES AND ACTIVE GALAXIES

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In this paper we studied differences of the stellar population between the HII galaxies and active galaxies. We used full spectrum fitting technique to analyse the composite stellar population spectrum made of a number of bursts. We looked for correlations between the fraction of the youngest population to the total flux and the total equivalent width, as well as to the fraction of the sum of the two youngest to the total flux and the total equivalent width. We found that the population of HII galaxies is younger than that of active ones.

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# CRYOPLASMA IN HELIUM INDUCED BY CORONA DISCHARGE

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Fluorescence spectroscopy is a powerful tool to obtain information on microscopic processes in non-equilibrium discharge plasma (corona) in dense media such as high pressure supercritical gas and even liquids. Spectroscopic observations of the light emitted by ionized gases can be used to determine structural information of the local environment of the emitting atoms or molecules. An ionization zone near a tip electrode is the source of light emitted by the corona.

A cryoplasma has been realized in laboratory conditions using corona discharge in gaseous and liquid Helium at cryogenic temperatures of the matter, Tg $<$ 100 K. Experiments were carried out at a number of fixed temperatures 300 K down to 4.2 K under high pressures 0.1$\div$10 MPa. The conditions covered a wide region of thermodynamic states of the matter such as from a gas with density of $10^{20}$ cm$^{-3}$ up to liquid Helium with density of $2*10^{22}$ cm$^{-3}$.

Our analysis showed that conventional impact pressure broadening theory is inadequate for the description of the observed widths and shifts. The impact theory predicts broadening and shifts of atomic lines that are small due to the low temperature of the medium. In contrast, static (statistical) distortion of lines is important. The long-range He*-He repulsive potential has been used for calculation of the line shape within the framework of the static approximation theory. It is shown that atomic lines have asymmetric profile in the case of dense gas. A symmetric Gauss-like profile has been observed for lines in liquid He. Such a line shape is the result of creation of a micro-cavity around the excited atoms.

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# STARK BROADENING OF B IV LINES FOR ASTROPHYSICAL AND LABORATORY PLASMA RESEARCH

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The study presents Stark broadening parameters (widths and shifts) of B IV spectral lines determined using Sahal-Bréchot theory based on the semi-classical perturbation formalism [1, 2]. Data on Boron lines are of interest in astrophysics, astrochemistry, and cosmology, in technological plasma research, for thermonuclear reaction devices, and for laser produced plasma investigation. For abundance determinations of boron and modellisation and analysis of stellar plasma it is necessary to have reliable atomic and spectroscopic data, including Stark broadening parameters. This enable to provide data on the astrophysical processes that can both produce and destroy this rare element. Namely, the light elements lithium, beryllium, and boron (LiBeB) are sensitive probes of stellar models due to the fact that the stable isotopes of all three consist of nuclei with small binding energies that are destroyed easily by (p, a) reactions at modest temperatures [3]. The origin and evolution of boron are of special interest because it is hardly produced by the standard big bang nucleosynthesis (BBN), and cannot be produced by nuclear fusions in stellar interiors [4]. The cosmic abundance of 11B is of major importance for the model of Galactic chemical evolution (GCE) [5]. In Ref. [5] authors concluded that a major portion of the cosmic abundance of 11B can be attributed to neutrino nucleosynthesis. Thus, it is necessary to accurately describe the stellar evolution, and the formation of elements, which are closely connected. To make progress in these developments chemical abundances are crucial parameters to be determined. This needs an accurate interpretation of the detailed line spectra of the stellar objects.

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# CHARGE EXCHANGE PROCESSES AND X-RAY EMISSION OF PLANETS AND COMETS IN SOLAR SYSTEM

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A surprising observation was made in 1996 of X-ray emissions from the comet Hyukatake using the ROSAT satellite. One of the mechanisms believed to be contributing to this surprisingly strong emission is the interaction of highly charged solar wind ions with planet atmospheres and comet gases. My lecture will present the review of total absolute charge and normalized line-emission (X-ray) cross-sections for collisions of high-charge state ions with planetary and comet species. The importance of applying accurate cross-sections, including double charge exchange, to obtain absolute line emission intensities is emphasized.

I shall discuss the situation with the current and projected launch of X-ray satellites which provide higher resolution observations.

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# SPECTRAL LINE WIDTHS IN STELLAR ATMOSPHERE MODELLING IMPROVEMENTS, CHALLENGES, PERSPECTIVES

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Accurate line synthesis using model spectra has always been at the foundation of the detailed spectral analysis of stellar parameters. Often, many line parameters like oscillator strengths and damping constants have been fine-tuned in line-by-line analysis in a semi-empirical manner. But as atmosphere models have grown in complexity, they now may include millions of atomic, and literally billions of molecular lines. The latter in particular have become necessary to accomodate as models have advanced well beyond the end of the classical main sequence into the substellar domain, approaching now with spectral class Y brown dwarfs the temperature regime of habitable planets. The same types of models may also be applied to the atmospheres of extrasolar planets; initially hot Jupiters and other gas giants, but now targetting Neptune- and super-Earth-type planets as well. This progress towards cooler temperatures requires the inclusion of not just diatomic molecules, but tri-, tetra-, pentatomic and even more complex compounds. These display the aforementioned extremely complex bands with some $10^8 - 10^9$ transitions contributing to the opacity. At the same time, more powerful high-resolution spectrographs on VLT-class telescopes now allow to study even the faintest red dwarf stars and some brown dwarfs at a resolution that used to be available only for bright stars. To reproduce the full comlplexity of these spectra, atmosphere models therefore have to rely largely on theoretically determined line parameters. For example, collisional damping widths based on quantum-mechanical calculations have become available for some thousands of atomic lines under typical stellar conditions, and detailed line shapes for much more complex broadening as it occurs in very cool brown dwarf atmospheres, exist for a few important transitions. I will discuss how these data have driven the improvement of high-resolution spectral synthesis, and which data are needed most urgently to keep up with the further advance towards cooler sources, different metallicities and high-quality observations covering a wide spectral range from the optical to the mid-infrared.

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# NEW RESULTS FROM INTEGRATED SPECTROSCOPY OF NEARBY GALAXIES IN THE HERSCHEL REFERENCE SURVEY

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We investigate the relationships between stellar mass, metallicity and gas content for a sample of nearby late-type galaxies in different environments. We derive oxygen abundances using new integrated, drift-scan optical spectroscopy and the metallicity calibrations of Kewley & Ellison (2008). Combined with ultraviolet to near-infrared photometry and HI 21 cm line observations, we reconstruct the stellar mass - metallicity relation. We find that, at fixed stellar mass, galaxies with lower gas fractions typically also possess higher oxygen abundances. We also observe a relationship between gas fraction and metal content, whereby gas-rich galaxies are typically metal-poor. Statistically, the stellar-mass metallicity relation is invariant to the environment. We demonstrate how some gas deficient cluster spirals may only appear to be more metal-rich compared to their field counterparts. These results indicate that internal processes, rather than environmental effects, play a key role in shaping the stellar mass-metallicity relation.

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# COMPOSITE PROFILE OF THE Fe K$\alpha$ SPECTRAL LINE EMITTED FROM A BINARY SYSTEM OF SUPERMASSIVE BLACK HOLES

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Binary systems of supermassive black holes (SMBHs) originate in galactic mergers and it is believed that their coalescences represent the most powerful sources of gravitational waves. Electromagnetic radiation in different spectral bands emitted during such coalescences represents the most direct evidence for the formation of such binary systems, as well as their essential observational signatures. At some stage during galactic merger, two SMBHs initially carried within the bulges of their host galaxies, will become gravitationally bound and will start to orbit around their center of mass with velocities of a few thousand km s$^{-1}$. In such cases, accretion of the surrounding matter on both SMBHs could be expected, and as a result, a strong X-ray emission in the broad Fe K$\alpha$ line at 6.4 keV might be observed. We developed a model of a relativistic accretion disk around a SMBH, based on ray-tracing method in the Kerr metric, and used this model to study the variations of the composite Fe K$\alpha$ line emitted from two accretion disks around SMBHs in a binary system. We assumed that in this first stage the orbit of such a binary system is approximately Keplerian and simulated the composite line shapes during different orbital phases and for different mass ratios of the SMBHs. The obtained results show that, if observed, such composite Fe K$\alpha$ line profiles could be used for constraining several orbital elements of the binary system and some parameters of its components.

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# THE RELATIONSHIPS BETWEEN SPECTRAL PROPERTIES OF ACTIVE GALACTIC NUCLEI TYPE 1

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In order to investigate the AGN spectral properties in the optical and UV range, we choose the sample of 300 AGNs type 1 from Sloan Digital Sky Survey (SDSS). Their emission lines are fitted with multiple Gaussian functions, where each Gaussian represents the emission from one emission region. The optical and UV iron lines are fitted with a template.

Since the line parameters, obtained from the best fit, reflect the physical and kinematical properties of the regions where they arise, we investigate the relationships between kinematical properties of the UV and optical lines and their components, in order to find if there are any kinematical connections between their emission regions. The relation between emission lines and continuum luminosity (Baldwin effect) is analyzed, but specially for different line components, which are assumed to arise from different emission regions. The new model of Balmer continuum is proposed, and we apply it in order to investigate the properties of the UV continuum. The influence of starbursts to AGN spectral properties is investigated, and we found that objects, which should be expected to have significant contribution of starburst emission, have significantly different correlations between some spectral properties.

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# THE OPTICAL EMISSION LINES OF TYPE 1 X-RAY BRIGHT ACTIVE GALACTIC NUCLEI

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A strong X-ray emission is one of the defining signatures of nuclear activity in galaxies. According to the Unified Model for Active Galactic Nuclei (AGN), both the X-ray radiation and the prominent broad emission lines, characterizing the optical and UV spectra of Type 1 AGNs, are originated in the innermost regions of the sources, close to the Super Massive Black Holes (SMBH), which power the central engine. Since the emission is concentrated in a very compact region (with typical size $r \leq 0.1\,\mathrm{pc}$) and it is not possible to obtain resolved images of the source, spectroscopic studies of this radiation represent the only valuable key to constrain the physical properties of matter and its structure in the center of active galaxies. Based on previous studies on the physics of the Broad Line Region (BLR) and on the X-ray spectra of broad ($\mathrm{FWHM}_{\mathrm{H}\beta} \geq 2000\,\mathrm{km\,s^{-1}}$) and narrow line ($1000\,\mathrm{km\,s^{-1}} \leq \mathrm{FWHM}_{\mathrm{H}\beta} \leq 2000\,\mathrm{km\,s^{-1}}$) emitting objects, it has been observed that the kinematic and ionization properties of matter close to the SMBHs are related together, and, in particular, that ionization is higher in narrow line sources. Here we report on the study of the optical and X-ray spectra of a sample of Type 1 AGNs, selected from the Sloan Digital Sky Survey (SDSS) database, within an upper redshift limit of $z = 0.35$, and detected at X-ray energies. We present analysis of the broad emission line fluxes and profiles, as well as the properties of the X-ray continuum and Fe $K\alpha$ emission and we use these parameters to assess the consistency of our current AGN understanding.

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# STUDYING THE COMPLEX BAL PROFILES OF Si IV IN 30 BALQSOs SPECTRA

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Most of Broad Absorption Lines (BALs) in quasars (QSOs) present very complex profiles. This means that we cannot fit them with a known physical distribution. An idea to explain these profiles is that the dynamical systems of Broad Line Regions (BLRs) are not homogeneous but consist of a number of density clouds with different physical parameters. Each one of these density regions gives an independent classical absorption line. If the regions that give rise to such lines rotate with large velocities and move radially with small velocities, the produced lines have large widths and small shifts. As a result they are blended among themselves as well as with the main spectral line and thus they are not discrete. Based on this idea we study the BALs of UV Si IV resonance lines in the spectra of a group of High Ionization Broad Absorption Line Quasars (HiBALQSOs) using the Gauss-Rotation model (GR model).

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# ACCELERATING MULTIDIMENSIONAL NLTE RADIATIVE TRANSFER USING FORTH-AND-BACK IMPLICIT LAMBDA ITERATION

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State-of-the-art methods in multidimensional NLTE radiative transfer are currently based on local approximate lambda operator, and accelerated either by applying Ng acceleration to Jacobi iteration, or by accelerating Gauss-Seidel technique via SOR and SSOR methods. Formal solution is almost exclusively based on the short characteristics approach. Here we offer another type of acceleration, based on FBILI approach developed for 1D NLTE radiative transfer problems. In the formal solution of the RT equation we use two-point algorithm, i.e. we take into account the values of source function and its derivative at local and upwind points only. We introduce an implicit representation of the source function in the computation of the intensities by computing and storing the coefficients of the linear relations $J = a + bS$ in all directions. Here the coefficient $b$ is similar to the local operator used in other approaches. The coefficients of the linear relations are then used to update the values of the source function to be exploited as soon as they are available in a process similar to Gauss-Seidel method. Further acceleration is achieved by introducing iteration factors in the coefficient $b$. The preliminary results show substantial acceleration as compared to the above mentioned techniques.

## SPECTRAL LINE BROADENING BY RELATIVISTIC ELECTRONS IN PLASMAS: COLLISION OPERATOR SPECTRAL LINE BROADENING BY RELATIVISTIC ELECTRONS

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Regarding the electron broadening of the line in plasma, we have calculated the amplitude of the collision operator. This calculation takes into an account the relativistic mass of the free plasma electrons in the description of the dynamics. First, we have assumed that the relativistic free electron moves in the Coulomb potential due to an impurity ion with a net charge (+Ze): we compute the electron trajectory around this impurity and the electric autocorrelation function on the same impurity is derivated. At the second stage, the free relativistic electrons are assumed to move in the effective potential that we have calculated in the mean field approximation: again, the trajectory, around the impurity ion, of the relativistic free electron and the the electric auto-correlation function are computed. In both cases, the amplitude of the collision operator is calculated. The comparison between the relativistic and the classical calculations are done for all the relevant quantities.

## PHOTO-IONIZATION IN THE IONOSPHERIC D REGION INDUCED BY THE SOLAR Ly-$\alpha$ LINE EMISSION

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The hydrogen Ly-$\alpha$ line has a dominant influence in photo-ionization processes in the unperturbed terrestrial ionospheric D region. In this paper, we present a procedure to calculate the rate of photo-ionization induced by Ly-$\alpha$ photons during periods after solar X-flare occurrences. This theory is applied to the case of a flare from May 5, 2010 and conditions typical of the upper half of the D region where all other perturbers have a negligible influence. The necessary data on low ionospheric plasma parameters were collected by the very low frequency (VLF) radio-wave technics. The electron concentration is calculated from the amplitude and phase of the VLF signal emitted by the DHO transmitter in Germany and recorded by a receiver located in Serbia, while the introductory data on the X radiation intensity in the wavelength range 0.1 - 0.8 nm were registered by GOES-14 satellite.

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# REVERBERATION MAPPING OF THE HIGH LUMINOSITY QUASAR PG 1247+268

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Virial estimates of the black hole mass in the center of AGNs, derived from single-epoch observations of luminosity and emission line widths, are now available for several thousands of objects at all redshifts and luminosities, so that studies of the cosmological evolution of the AGN mass function are becoming possible. These estimates are based on the empirical luminosity-size relation measured through reverberation mapping at low redshifts and luminosities. For this reason the spectrophotometric monitoring of 4 luminous quasars was started in 2003, with the 1.8 m telescope of the Asiago Observatory. To measure the reverberation time lag we adopt a method, recently introduced by Zu et al. (2011), which takes advantage of the available statistical information on variability autocorrelation and makes simple assumptions on the continuum-emission line transfer function. We present the estimate of the broad line region size and black hole mass for the quasar PG 1247+267, which is the most luminous object with reverberation measures to date. Measures with both CIV and CIII] emission lines provide consistent results. A possible flattening of the size-luminosity relation at high luminosity is suggested.

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# THE INTRINSIC BALDWIN EFFECT IN A SAMPLE OF AGNs WITH BROAD LINES

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We investigated intrinsic Baldwin effect (IBE), negative correlation between the equivalent widths of emission lines and the continuum luminosity in active galactic nuclei, in three objects: NGC 4151, NGC 5548 and 3c390.3. Data used were taken from several long-term monitorng campaigns. We found that in all three objects in some period the IBE may be present, but significant IBE can be detected only in NGC 4151. We showed that the slope of the intrinsic Beff in NGC 4151 is changing in the time In addition using the CLOUDY code to model the BLR of the NGC 4151 we found that the slope of the intrinsic Beff depends on the distance from the source of the ionizing continuum.

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# PROBING THE EVOLUTION OF ACTIVE GALACTIC NUCLEI USING THE IRON K$\alpha$ LINE

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Active Galactic Nuclei (AGN) are the most powerful persistent sources of radiation in the Universe. A large fraction of the AGN output power is emitted in the X-rays, in a region very close to the supermassive black hole (SMBH). The most distinctive feature of the X-ray spectra of AGN is a narrow iron K$\alpha$ line, thought to be produced in the circumnuclear material, likely in the molecular torus. Given its origin, the iron K$\alpha$ line is possibly the most important tracer of the matter surrounding the supermassive black hole. One of the most interesting characteristics of the Fe K$\alpha$ line is the decrease of its equivalent width ($EW$) with the continuum luminosity, the so-called *X-ray Baldwin effect* (Iwasawa & Taniguchi 1993). Several explanations have been proposed in the last decade to explain this effect: i) a luminosity-dependent variation in the ionisation state of the iron-emitting material (Nandra et al. 1997); ii) the decrease of the number of continuum photons in the iron line region with the Eddington ratio, as an effect of the known photon index-Eddington ratio correlation (Ricci et al. submitted); iii) the decrease of the covering factor of the torus with the luminosity (e.g., Page et al. 2004) as expected by luminosity-dependent unification models (e.g., Ueda et al. 2003). In my talk I will review the main characteristics of the Fe K$\alpha$ line, and present the results of a recent work aimed at explaining the X-ray baldwin effect using an iron-line emitting physical torus model with a luminosity-dependent covering factor (Ricci et al. 2013).

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# MULTI-EPOCH ABSORPTION LINE VARIABILITY OF APM 08279+5255

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Broad Absorption Line (BAL) variability potentially represents a powerful tool to investigate the physical nature and the structure of gas outflows in active galactic nuclei. Most existing BAL variability studies rely on observations taken at a few epochs for samples of tens of BAL QSOs. In the present study we present the first "monitoring" of a single object, APM 08279+5255, which has been observed with the 2.8 m telescope at the Asiago Observatory more than 20 times since 2003. All available spectra from the literature have also been analysed, including two high resolution spectra, from Keck and HST respectively, extending the time interval from 1998 to 2012. A remarkable stability of the shape of the absorption profile is found. At the same time significant variations of the equivalent width are observed. A correlation of the BAL equivalent width with the QSO luminosity is found for the first time. These results suggest that changes in the ionisation and excitation state of the gas are causing opacity changes.

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# SPECTROSCOPY PECULIARITIES OF THERMAL ELECTRIC ARC DISCHARGE PLASMA BETWEEN COMPOSITE ELECTRODES Ag-$SnO_2$-ZnO

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The wide application of composite materials in contacts or electrodes of switching devices in the electrical industry stimulate the growing interest in studying of plasma of electric arc discharges between electrodes produced from such kind materials. The composition optimization of an appropriate composite material is the problem of great importance at the moment. Therefore it seems reasonable to carry out the investigations of plasma parameters in a discharge gap with the aim to reach the perfect erosion properties of composite electrodes. Usually the determination of plasma parameters is performed by optical spectroscopy techniques in most cases. However the utilization of such methods is impossible without careful selection of emitted spectral lines and their spectroscopic data as well. This report deals with the experimental attempt to verify the atomic data of ZnI spectral lines, which one can find in the up-to-date data bases. The free burning arc between the composite Ag-$SnO_2$-ZnO electrodes was used as the thermal plasma source with zinc and silver vapours at the first stage. We carefully selected just those data of ZnI lines, which were in line with the same slope of the populations of AgI lines in the Boltzmann plot in an assumption of local thermodynamic equilibrium. The previously selection of silver spectral lines and atomic data was carried out. At the next stage of investigation the free burning electric arc between the brass electrodes was used as the thermal plasma source with zinc and copper vapours to verify the obtained atomic data of ZnI spectral lines. In this case the reliable CuI spectral lines and atomic data were used. At the final stage of our study the laser absorption plasma spectroscopy of arc discharge between brass electrodes was carried out to examine the assumption of local thermodynamic equilibrium. The equilibrium plasma composition calculated on the base of radial temperature and electron density obtained experimentally by optical emission spectroscopy was compared with results of absorption spectroscopy. It was found that investigated plasma source at arc current of 3.5 A and 30 A is an equilibrium state. So, in a result of such complex investigation the following spectral lines ZnI 462.9, 468.0, 472.2, 481,0. 636.2 nm and relevant atomic data can be recommend to use in plasma diagnostics and for line shape calculations as well.

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# RELATIVE DEVIATION OF QSO SPECTRA INDUCED BY THE MICROLENSING ON DIFFUSIVE MASSIVE SUBSTRUCTURE

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The small mass structures dispersed throughout the galaxies are perfect candidates for gravitational lensing on milli and micro scale. The aim of this paper is to investigate this effect and present the results as a relative deviation of spectra during the milli/microlensing event. We take the QSO as a distant source where most of the radiation comes form the accretion disc surrounding the AGN core. We observe the emitting radiation in the narrow region from infrared toward the hard UV band, separated in four emitting bands, U, B, V and R. We calculate the ratio of observed flux with and without lens influence and present it as the relative deviation in different bands. That allow us to explore conditions when the spectra deviation is most significant. We conclude that microlens directly influence the magnification of the observed object, but also its position, which could be characterized in a form of centroid shift.

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# ABSORPTION QUASI-MOLECULAR BANDS AS FACTORS OF THE SOLAR PHOTOSPHERE OPACITY ABOVE SUNSPOTS

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In the previous work it was shown already that the radiative processes in strongly non-symmetric ion-atom collisions in the solar photosphere generate the absorption quasi-molecular bands in UV and VUV regions which could significantly influence on the opacity of the quiet Sun atmosphere [1]. The aim of this research is to show that the similar absorption quasi-molecular bands may be of the same importance also for the solar photosphere opacity above sunspots. Within this work the H+A+ ion-atom collision systems, where A is the relevant metal atom (A = Mg, Ca, Na, Si, Al), are taken into account. Here, the non-symmetric radiative processes are considered under the conditions characterizing the corresponding umbral model [2], which gives the possibility to perform all needed calculations and determine the corresponding spectral absorption coefficients. The needed characteristics of the corresponding molecular ions, i.e. molecular potential curves and dipole matrix elements, have been determined. The examined processes generate rather wide quasi-molecular absorption bands in the UV and VUV regions, whose intensity could be comparable with the relevant concurrent radiative processes including here the so called $H^-$ continuum. The presented results suggest that the non-symmetric ion-atom absorption processes have to be further examined and consequently could be included in standard models of the sunspot atmosphere.

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# INFRARED EMISSION OF THE AGN DUSTY TORUS: RADIATIVE TRANSFER MODELING WITH SKIRT

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We investigated the infrared emission of a toroidal structure of gas and dust (the "dusty torus") surrounding the central regions of the AGNs. We introduced a new model of the the dusty torus as a clumpy two-phase medium, with high-density clumps embedded in a low-density interclump dust. To obtain spectral energy distributions and images of the torus at different wavelengths, we employed the 3D Monte Carlo radiative transfer code SKIRT. We calculated a grid of models for different parameters, analyzed the properties of infrared emission and compared them to the properties of the corresponding sets of clumps-only models and models with a smooth dust distribution. We found that the most striking feature of the two-phase model is that it might offer a natural solution to the common issue reported in a number of papers — the observed excess of the near-infrared emission. Namely, a torus model with the dust distributed in a two-phase medium has a more pronounced ('hotter') emission in the $2 - 6$ $\mu$m range while displaying, at the same time, an attenuated 10 $\mu$m silicate feature.

# STUDYING THE COMPLEX BAL PROFILES OF C IV IN 30 BALQSO SPECTRA

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As we know, HiBALQSOs present broad and very complex absorption lines. Although in our days we accept that these lines are the synthesis of independent absorption lines which are created in different absorbing clouds known as Broad Line Region Clouds, a thorough study of the absorbing regions has not yet been accomplished. This lies on the fact that the radiative transfer equation for a complex atmospheric plasma region (comprised of many clouds) was not solved. Danezis et al. [1] solved the radiative transfer equation for such a complex structure and proposed the GR model [2] for the study of complex spectral line profiles. In this work, using the GR model, we study the UV absorption lines of C IV in the case of 30 HiBALQSOs. Based on our spectral analysis we succeeded in reproducing theoretically the complex absorption profiles and calculating a series of physical parameters for the absorbing clouds (radial and rotational velocities of plasma clouds, random velocities of ions inside the plasma clouds, absorbed energy, FWHM of the corresponding spectral lines, column density, optical depth). Last but not least, by correlating all of these physical parameters we managed to extract general conclusions about the physical structure and kinematics of plasma clouds that create the UV absorption lines of C IV in HiBALQSOs.

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# SHAPE MODELLING WITH FAMILY OF PEARSON DISTRIBUTIONS

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The choice of the best-suited statistical distribution for data modelling is not a trivial issue. Unless a sound theoretical background exists for selecting a particular distribution, one will usually resort to testing various candidates and select a distribution based on its fit to the observed data. While this is a legitimate strategy, it is more objective and efficient to define a sufficiently general family that can be used for this purpose. This approach has a long tradition in statistics, and resulted in various families of distributions, most notably Pearsons. The Pearson distributions are widely used family of distributions to approximate empirical data, with a wide diversity of distribution shapes. The variety of shapes offered by this family includes unimodal, bimodal, U-shaped, J-shaped and monotone probability distribution functions, which may be symmetric and asymmetric, concave and convex, with smooth, abrupt, truncated, long, medium or short tails. On one hand, the ability of Pearson distributions to take this great diversity of shapes is responsible for wide application in actual modelling of measurements, and, on the other hand, the estimation of the distribution parameters requires only first four central moments calculated from the measurements minimizing the error propagation. The basic properties of the family members are discussed and numerical procedures for determining appropriate parameters using maximum likelihood estimation and method of moments are introduced. As an illustration of the distribution family and methods, a practical implementation is applied to data sets of electric field of Langmuir waves measured by WIND satellite yielding to a new insight in a long-lasting problem in beam-plasma interaction mechanisms.

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# UTILIZING GRAPHIC PROCESSING UNITS FOR LARGE SCALE SIMULATIONS: EXAMPLE OF DUST DYNAMICS IN AGB BINARY WINDS

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Graphic Processing Units (GPUs) are easily accessible massively parallel processors with a large low-cost computing capability. GPUs are now the most powerful processor in a desktop computer. Development of new GPUs continues to outpace progress in CPUs due not only to its highly data-parallel nature but also to its ability to achieve higher arithmetic intensity. These characteristics gradually transform GPUs into the mainstream numerical accelerators in the heterogeneous supercomputing environments. However, unlike traditional CPUs that have been studied by researchers for long time, the fast evolving GPU technology is still considered as a mysterious innovation by general users/developers. In this presentation I will demonstrate a simple example of GPU usage for computation of dust dynamics in a stellar wind driven by radiation pressure force from a binary - an AGB star and its main sequence companion. The equation of motion is modified according to some specifics of AGB winds dynamics. We use a simple leap-frog integration scheme. Overall, at least several million integration steps are performed in a typical simulation producing a 2D image of the dusty cloud integrated over 2000 years. I will show basic building blocks of the GPU code written in C with CUDA library, demonstrate problems caused by colliding memory requests on GPUs, and show some illustrative examples of speed ups by a factor of serval hundreds (reducing computational time from a couple of days to minutes).

*Contributed papers*

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# SHAPE OF ATOMIC LINES EMITTED BY POSITIVE CORONA DISCHARGE

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The corona discharge on point anode (positive corona) was realized if a radius of the electrode was small enough, 0.45$\mu$m, and voltage was some larger than that in the case of the negative corona. The mobility of electrons and positive ions are close each other in LHe. Therefore, electric currents both negative and positive corona differ weakly. However the spectral analysis of the radiation from the positive corona shows qualitative differences of spectral features of these discharges. Both atomic lines and molecular bands were observed in the spectra of the positive corona in LHe at 4.2K under different pressures. The spectra observed in the positive corona have marked non-symmetric shape. The atomic spectra show an increased intensity of their long-length "red" tails. The red satellites have been observed in the vicinity of both atomic and molecular lines. Comparison of intensities of R- and P-branches of the rotational structure of band $d^3\Sigma_u^+$ - $b^3\Pi_g$ shows increased intensity of the P-branch lines. This effect is more significant than in spectra of negative corona.

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# LINE PROFILES OF Li-$H_2$

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Alkali line profiles based on pseudo-potentials of Rossi and Pascale [1] have been included in atmosphere program PHOENIX for the computation of atmosphere models and synthetic spectra, this was a major improvement compared to previous calculations of Allard et al. [2] who included Lorentzian profiles using van der Waals damping constant to generate atmosphere models of brown dwarfs.

In this work we report new Li-$H_2$ *ab initio* potentials and transition dipole moment functions calculated for several collision geometries and present new theoretical Li line profiles and their dependence with temperature.

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# COLLISIONAL PROFILES OF IONIZED CALCIUM PERTURBED BY HELIUM

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In continuation of Homeier et al. [1] and Allard et al. [2] where we presented absorption spectra of Na-He in cool white dwarfs, we extend this work to the $Ca^+$-He system. The perturber density in the lineforming region of an ultra-cool WD atmosphere can reach the value of $10^{21}$ cm$^{-3}$, multiple perturber effects are taken into account using an expansion in density [3]. New diabatic potentials compared to pseudo-potentials of Czuchaj et al. [4] are used to evaluate the line wings.

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# LiHe SPECTRA FROM BROWN DWARFS TO HELIUM CLUSTERS

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The detection of Li I lines is the most decisive spectral indicator of substellarity for young brown dwarfs with masses below about 0.06 solar mass [1]. Detailed knowledge of the line profiles as a function of temperature and pressure can be obtained from semi-classical calculations using accurate molecular potential energy curves and dipole transition moments for the alkali-perturber system. The line profiles can then be used as valuable diagnostics of the atmospheres of brown dwarfs and extra-solar planets. Over a limited range of density and temperature, laboratory measurements can be used to validate the potentials which support the spectral line profile theory [2, 3].

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## DETECTING OUTFLOWS IN SUPER MASSIVE BINARY BLACK HOLE SYSTEMS

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Light curves and emission lines radial velocity curves from super massive binary black hole (SMBBH) systems shows some periodical variations that differ from expected Keplerian orbital signatures. Those variations are with shorter periodicity than the orbital period of binary system. These shorter variations might be due to outflows, jets or biconical winds. Here we present case studies, with possible outflow models.

## ON THE STARK BROADENING PARAMETERS OF SPECTRAL LINES OF NEUTRAL NEON

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In order to complete Stark broadening data for Ne I spectral lines, needed for analysis of stellar atmospheres, we determined, within the semiclassical perturbation method, the missing data for the broadening by collisions with electrons, protons and ionized helium, for 25 spectral lines of neutral neon. The obtained data will be included in the STARK-B database, which is a part of the Virtual Atomic and Molecular Data Center.

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# STRUCTURAL AND COLLISIONAL DATA FOR Mg III AND Al IV

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Neon-like ions have a high abundance over a wide range of electron temperatures and densities because of their closed-shell configuration ground state. Therefore, they play an important role in the diagnostics of a wide variety of laboratory and astrophysical plasmas. They are used to study transport and connement of high-Z impurity ions in tokamaks. They are of great interest for developing soft X-Ray and VUV lasers [1,2]. Atomic and collisional data for some Neon-like ions are missing in many known databases such as CHIANTI [3]. Collision strengths for Mg III and Al IV ions are examples of such missing data. This fact is the main idea behind the present work. We present here energy levels, oscillator strengths, radiative decay rates and fine structure collision strengths for these two ions. The radiative atomic data have been calculated with the code AUTOSTRUCTURE [4] where, besides the one-body and the two-body ne structure interactions, the two-body non-fine structure ones (contact spin-spin, orbit-orbit, Darwin...) have been taken into account. The scattering problem has been treated in the Breit-Pauli distorted wave approximation using the same code AUTOSTRUCTURE. Eleven configurations (yielding 75 levels) are included in our calculations: $(1s^2)$ $2s^22p^6$, $2s^22p^53l$, $2s2p^63l$, $2s^22p^54l$. Good agreement has been found between our radiative data and the available experimental and other theoretical ones. Collision strengths have been calculated for a large range of electron energy above all thresholds (reaching 240 Ry). No other collision strengths results for comparison.

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# QUANTUM STARK BROADENING OF Ar XV LINES

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Stark broadening mechanism is important in stellar spectroscopy, astrophysical and laboratory plasmas analysis. Its influence should be considered for the opacity calculations, the modelling of stellar interiors, the estimation of radiative transfer through the stellar plasmas and for the determination of chemical abundances of elements [1]. The need for spectral line broadening calculations is stimulated by the development of computers. Moreover, the development of instruments and space astronomy, such as the new X-ray space telescope *Chandra*, stimulated the calculations of line broadening of trace elements in the X-ray wavelength range. The recent discovery of the far UV lines of Ar VII in the spectra of very hot central stars of planetary nebulae and white dwarfs [2] showed the astrophysical interest for atomic and line broadening data for this element in various ionization states. Ar XV is one of these important ions. The only Ar XV line broadening calculations existing in the literature are the semiclassical ones [3,4], where the authors claimed that there are no experimental or other theoretical results for a comparison. Using our quantum formalism [5,6], we perform in the present paper quantum Stark broadening calculations for some Ar XV spectral lines within the X-ray wavelength range. Detail comparisons show an acceptable agreement with the semiclassical results.

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## PHYSICAL PARAMETERS OF THE RELATIVISTIC SHOCK WAVES IN A SAMPLE OF GRBs WITH MULTI-PEAKED LIGHT-CURVES

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The Gamma Ray Bursts (GRB) are sudden, elusive phenomena. The current interpretation of these events involves a fraction of the huge amount of gravitational energy associated with the formation of compact objects. This energy is deposited as kinetic energy of thin shells of material in a relativistic collimated outflow. The interactions among these shells and the presence of shocks yield to the GRB prompt emission. Despite this acknowledged sketch of the so called Internal Shock model, even after decades we still do not know much about the physical characteristic of these phenomena. In this work we develop a modified phenomenological model that reproduce the physical situation during the prompt $\gamma$-ray emission in a catch-up scenario (Simić & Popović, 2012) and we apply it to fit a sample of GRBs with multi-peaked light-curves. From the fitting procedure then we can extract basic parameters of the relativistic shock waves and look for various correlations among them, in order to give more detailed sight behind the GRB events.

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# ON THE STARK BROADENING OF Pb IV SPECTRAL LINES WITHIN THE 3000-7000 Å SPECTRAL RANGE

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Stark broadening parameters for 113 spectral lines of triply charged lead ion (Pb IV), have been determined recently, using semi-classical perturbation approach within the impact approximation. Spectral line widths and shifts have been obtained for temperatures from 20 000 K to 300 000 K and for an electron density of $10^{17}$ cm$^{-3}$. The complete obtained results and their analysis and comparison with other theoretical and experimental data will be published in MNRAS. Here are presented results for 31 spectral lines from the 3000-7000 Å spectral range in the visible part of the spectrum.

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# SEMICLASSICAL PERTURBATION STARK WIDTHS FOR DOUBLY CHARGED ARGON SPECTRAL LINES

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Argon in various ionization stage is observed in many astrophysical object. Doubly charged argon (Ar III) spectral lines are observed in high-resolution ultraviolet spectra of five sdB stars [1]. Ar III spectral lines are also observed in laboratory plasma [2]. As for diagnostics of stellar plasmas, Stark broadening parameters are used in the determination of temperature and density of laboratory plasmas.

Using semiclassical perturbation approach in the impact approximation, we have determined Stark widths for 20 Ar III spectral lines. Oscillator strengths needed for this calculation are obtained using Hartree-Fock relativistic (HFR) approach [3] and an atomic model including twelve configurations. Our widths are compared with experimental results of Djurović et al. [4], Bukvić et al. [5] and Djeniže et al. [6]. Stark widths of Ar III spectral lines can be useful for modelling and investigation of stellar atmospheres. Our results will be inserted in STARK-B database (http://vamdc.obspm.fr/) which is a part of Virtual Atomic and Molecular Data Center (VAMDC-http://vamdc.org/).

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## SENSING THE EARTH'S LOW IONOSPHERE DURING SOLAR FLARES USING VLF SIGNALS AND GOES SOLAR X-RAY DATA

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An analysis of four solar flare X-ray irradiance effects on VLF signal amplitude and phase delay variations on the GQD/22.1 kHz signal trace, during period of time from September 2005 to December 2006, was carried out. Solar flare data were taken from GOES12 satellite one-minute listings. For VLF data recordings at the Institute of Physics, Belgrade, Serbia, the AbsPAL system was used. It was found that solar flare events affected VLF wave propagation in the Earth-ionosphere waveguide in way that lower ionosphere electron density height profile changes, according to variation of estimated parameters, sharpness and reflection height, being different for these solar flare events.

## DATABASES IN ASTROPHYSICS: CHALLENGES AND OPPORTUNITIES

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We summarize Scientific Databases challenges and point out experiences which could be applied on problems facing Intelligence and Security Databases.

## TIME SERIES ANALYSIS OF ACTIVE GALACTIC NUCLEI ARP102B

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We have undertaken a ground-based monitoring campaign of active galactic nuclei Arp 102B with double-peaked broad line profiles, in order to improve the measurement of the size of its broad emission-line region and estimate the black hole mass. Here we give a report on application of two relatively new time series analysis techniques (z-transformed discrete correlation function (ZDCF) and damped random walk model) in handling our task.

## PROBABILITY OF FINDING CLOSE BINARY MASSIVE BLACK HOLES WITH ORBITAL PERIOD LESS THAN 15.6 YEARS

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Here we present the analysis of properties of binary massive black holes (BMBH) with mass ratio q=0.28, i.e. calculations of observable period range, mass dependence of characteristic semi-major axes, orbital-decay timescale evolution of these objects with a semi-major axis from 100pc to $10^{-4}$pc, and estimation of the total fraction of close BMHB with orbital period less than 15.6 years, in the frame of possible detection with the GAIA mission.

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## LOW IONIZATION LINES IN HIGH LUMINOSITY QUASARS

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In order to investigate where the and how low ionization lines are emitted in quasars, we are studying a new collection of spectra of the CaII triplet at $\lambda$ 8498, 8452, 8662 observed with the VLT Telescope using the ISAAC IR spectrometer. Our sample involves luminous quasars at intermediate redshift, for which CaII observations are almost non-existent. We fit the CaII triplet and the OI $\lambda$ 8446 line using the H$\beta$ profile as a model. We derive constraints on the line emitting region from the relative strength of the CaII triplet, OI $\lambda$ 8446 and H$\beta$.

## PHOTOIONIZATION ESTIMATES OF BROAD LINE REGION SIZE IN ACTIVE GALACTIC NUCLEI

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We present a method to determine the distance of the Broad Line Region (BLR) from the central continuum source in type-1 AGNs. Our method is based on the determination of the physical conditions in the BLR under the assumption that the line emitting gas is photoionized by the central continuum source. We derive "diagnostic" intensity ratios that involve UV lines Al III$\lambda$1860, Si III$\lambda$1892 and C IV$\lambda$1549. Diagnostic ratios allow us to compute the product of ionization parameter and hydrogen number density, and hence the BLR radius from the definition of the ionization parameter itself. We compare our determinations of the BLR radius with the ones independently obtained from reverberation mapping, in order to test the accuracy of our method. We also compare black hole masses obtained with the photoionization method to the ones derived from widely-applied correlations between mass, line broadening and luminosity.

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# POSSIBLE DETECTION OF THE GRBs AND $\gamma$-RAY ECHOS BY ANALYZING THE IONOSPHERIC PERTURBATIONS

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The radiation in different spectral domains (UV, soft and hard X and $\gamma$) is originated by various astrophysical phenomena and it is very important for dynamical processes in the terrestrial ionospheric plasma. However, the hard X and $\gamma$ rays influence on the ionosphere has been in a focus of only a few studies, since a problem with reliable detections of plasma perturbations induced by them are very hard due to a number of other perturbations with similar ionospheric plasma characteristics changes. In this paper, we study possibility of detection of the short time terrestrial low ionospheric response to gamma ray bursts (GRBs) and the $\gamma$-ray echo depending of their spectral characteristics and central impact points. Here, we give a statistical analysis of perturbations of the 24.0 kHz very low frequency (VLF) signals emitted by NAA transmitter (USA) and recorded by VLF receiver located in Belgrade (Serbia) during periods around 71 GRBs events registered by SWIFT satellite between 31.08.2009. and 09.09.2012.

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# THE TITANS OF THE UNIVERSE: RECONSTRUCTING THE HISTORY OF ACCRETION OF THE SUPERMASSIVE BLACK HOLES

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Nowadays, it is known that almost all galaxies have into their center a black hole with mass of thousands or billion of solar mass. However, the origin and evolution of these objects is not completely understood. In this work we study the accretion process of super massive black holes having as base the evolution history of the dimensionless mean accretion rate, weighted by Eddington luminosity, $\bar{\lambda}$. We use the Sloan Digital Sky Survey (SDSS) data release 7 (DR7) and the Catalog of Quasar Properties from SDSS DR7 [1]. Different of other works, here we determine the evolution of $\bar{\lambda}$ not only in redshift bins ( $0.0 \leq z \leq 4.5$), but also for bins of mass ($10^{7.5} - 10^{10}$ $M_{\odot}$). The $\bar{\lambda}$ was represented by double exponential (one in $z$ and another in $m_{bh}$) like Schechter parametric function, been that the parameters were determined using maximum likelihood estimation method. In this work we assume that the mean radiative efficiency of accretion disk is constant and that its value is $\bar{\eta} = 0.1$. We observe that the accretion rate peaks at redshift $z \sim 4.5$ and it reaches maximum value for black holes with $\sim 10^9 M_{\odot}$. The accretion rate behavior, in bins of mass, is similar to a Gaussian that peaks at $140 M_{\odot} yr^{-1}$, and it is a linear function up to redshift $\sim 4.5$.

[1] See https://www.cfa.harvard.edu/∼yshen/BH_mass/dr7.htm for more details

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# ATOMIC DATA AND STARK BROADENING OF CuI AND AgI SPECTRAL LINES: SELECTION AND ANALYSIS

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Composite materials on a base of copper and silver are widely used as electrode or contact materials in electric industry applications (e.g. relays, commutators, circuit breakers etc.). There are an insignificant number of experimental and theoretical papers, which deal with an investigation of surface condition, plasma parameters and arc discharge between such composite electrodes as well as single-component silver electrodes in the up-to-date literature. The main aim of this paper is AgI, CuI spectroscopic data selection and an investigation of plasma parameters of arc discharge between fabricated by a powder metallurgy technique composite electrodes Ag-CuO (90/10).The arc was initiated in air between the flat end surfaces of non-cooled rod electrodes. The electrode diameter was 6 mm; the discharge gap was 8 mm, the arc current were 3.5A and 30 A. The studies were realized by optical emission spectroscopy technique. Due to the spatial and temporal instability of the discharge, we used the method of one-pass tomographic recording of the spatial distribution of spectral line intensities. Fast scanning of the spatial distributions of the radiation intensities was performed using a Sony ILX526A 3000 pixel CCD linear array. Due to the instability of the discharge, the recorded spatial distributions of the radiation characteristics were statistically treated. We also took into account the no n-uniformity of the spectral sensitivity of the apparatus. Temperature radial profiles of electric arc discharge plasma were obtained using Boltzmann plot technique. For this purpose it is necessary to know the reliably examined spectroscopic data. However, there is a problem with a large variety of available in a nowadays literature spectroscopic data for these lines (transition probability, oscillator strength, stark broadening parameters etc.). Energy level populations' behavior on the Boltzmann plot was used for CuI and AgI spectroscopic data selection. In this way the selection of spectroscopic data for some of CuI, AgI lines was realized.

## ON THE STARK BROADENING OF Cr II SPECTRAL LINES IN ATMOSPHERES OF DB WHITE DWARFS AND A TYPE STARS

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Recently, new Stark broadening parameters for 9 resonant Cr II multiplets have been determined within the semiclassical perturbation approach. Obtained results have bean applied here, to the analysis of the Stark broadening influence on stellar spectral line shapes. We have demonstrated that Stark broadening is the principal broadening mechanism in DB white dwarf atmospheres, and may be non negligible in A-type star atmospheres, especially in the line wings and when the chromium is overabundant. The present analysis shows, that its neglection may contribute to errors in chromium abundance determination.

## STARK BROADENING DATA FOR SPECTRAL LINES OF RARE-EARTH ELEMENTS: Yb IV AND Nb III

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In order to provide a complete set of Stark broadening data for astrophysical purposes, we started a project to calculate such data for a number of spectral lines of the ionized rare-earth elements (REE). Here we present the Stark widths for ten Yb IV and Nb III spectral lines by using the modified semiempirical theory. Due to very complex spectra of ionized REE we have to improve the existing software. These results will be included in atomic date base for REE.

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# LYMAN-ALPHA BLOBS NUMBER DENSITY AND COLD ACCRETION MODE

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Lyman-alpha blobs (LAB) are objects that are in Lyman-alpha line very luminous $\sim 10^{43} - 10^{44}$ erg/s) and very extended ($\sim 50 - 100$ kpc in diameter) and radio quiet. LAB are discovered when Steidel et al. (2000) observed a protocluster of galaxies at $z = 3.1$ in narrow band Lyman-alpha survey. They are found mostly in protoclusters, and in less number in field. They are rare, number density of LAB at $z \sim 2 - 3$ is about $10^{-6}$ Mpc$^{-3}$ to $10^{-5}$Mpc$^{-3}$. Because of finding mostly in overdense regions and their rarity LAB could be related to formation of most massive galaxies. LAB are observed at $z \sim 1 - 6.6$, and mostly at $z \sim 2 - 3$. At $z < 1$ LAB are much rarer than at higher redshifts, in GALEX observation no LAB are found at $z = 0.8$, and later one LAB is found at $z \sim 1$. It is not still clear what is the source of energy of LAB. It is proposed that LAB could be powered by superwinds driven by starburst supernovae, by cooling radiation from cold streams of gas accreting onto galaxies, or by photoionisation by active galactic nuclei (AGN) or intense star formation. When observing LAB in different bands (e.g. X-rays) and when observing spectra of LAB, it appears that some LAB contain AGN, but that they are not energetic enough to power entire Lyman-alpha emission of LAB. Here we present our main results of comparing comoving density of LAB at different redshifts from different surveys with that from model in which LAB are powered by cooling gas.

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## PERTURBATIONS OF THE LOWER IONOSPHERE DUE TO THE $\gamma$, X AND UV STELLAR RADIATION

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The Belgrade system of VLF stations is simultaneous monitoring the properties of subionospheric propagating waves that reveal changes of the electrical properties of the ionospheric D-region during various stellar activities. These cosmic disturbances, $\gamma$, X and UV radiation, cause numerous complicated physical, chemical and dynamical phenomena in the lower ionosphere and may directly affect human activities. Besides a pure scientific interest to study the influence of this activity on the terrestrial atmosphere, the understanding and predicting the resulting turbulent regions of the ionosphere has important applications for radio communications, high-precision applications of global navigation satellite systems, etc. Among the high-energy phenomena that occur in the astrophysical context, probably the Soft Gamma-ray Repeaters(SGR)and the Gamma-Ray Bursts (GRB) are the most interesting. We show that the VLF technique is well suited to search for stellar events, and to provide a diagnostic of high-energy astrophysical phenomena.

## STARK-WIDTH REGULARITIES WITHIN SPECTRAL SERIES OF NEUTRAL ATOMS

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Stark-width dependences on the upper-level ionization potential within different spectral series of several neutral atoms have been studied and compared. Similar dependences have been found for electron- and proton-impact contributions to the Stark widths. The emphasis is on the term structure influence on the studied Stark-width dependences. Higher correlation between the empirical parameters were found when the temperature was increased. Neutral emiters were ranked by the regularity of their Stark broadening.

*Special session*

*"Spectral Lines and Polarization"*

*in the frame of COST action MP1104*

*"Polarisation as a tool to study the Solar System and beyond"*

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# SPECTROPOLARIMETRIC MONITORING OF THE SEYFERT GALAXY 3C 390.3 ON 6m TELESCOPE SAO RAS

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In 2008-2013 we carried out monitoring spectropolarimetric observations of the Seyfert galaxies 3C 390.3 (13 epochs) with the 6-meter telescope of SAO RAS with two variants of the spectrograph with a spectropolarimeter: SCORPIO-1 and SCORPIO-N in the spectral range (3500-9400) with the spectral resolution ∼40A and ∼10A, and the precision of linear polarization $< 0.3\%$ and $< 0.1\%$, respectively; the precision of instrument polarization $\sim 0.05\%$; We are analysed the results of spectropolarimetric observations of 3C390.3, using also some data from literature,(over 18 years, 1995-2013) and determined the Stokes parameters Q, U, degree of linear polarization P and the position angle of the polarization plane PA for continuum and for the emission line Ha, and also their variations with time. The following main results are received: integral flux and degree of polarization changes about twice; in continuum the linear polarization slightly increases as the wavelength decreases; in the Ha region the linear polarization is $\sim 1\%$ less than in continuum and its shape is box-like, without any structural details; in the region of lines and continuum the polarization angle (PA) of the E vector of linear polarization was changing during the monitoring period (18 years) by ∼(10-25) degrees; in polarized light the broad lines shifted by the value of order $10^3$ km/s to blue side relative to the systematic velocity were observed in the region of Ha and Hb; an anticorrelation of polarization plane angle variation in time relative to the continuum level was detected etc.

Delays (lags) between the polarized continuum and Ha and direct light from continuum and from Ha line are estimated.

We considered a model in which polarization in continuum results from vector addition of the slow-changing polarization of disk whose direction coincides with the jet direction, and the fast-changing polarization caused by synchrotron emission of the jet, whose polarization vector is approximately perpendicular to the jet direction. Thus, besides the fast-rotating Kepler disk forming broad hydrogen lines, the radial outflow of hot BLR gas with velocity of order of 1000 km/s is observed in the central region. This flux induces the polar scattering of continuous emission of the accretion disk, which leads to the observed depolarization of continuum emission under broad hydrogen lines.

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# INTERPRETING SPECTROPOLARIMETRIC RESULTS ACROSS A BROAD SPECTRAL RANGE - 3D RADIATIVE TRANSFER WITH THE STOKES CODE

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While constantly being underestimated, spectropolarimetric data often contains independent information about astrophysical objects and thereby complements spectroscopy or imaging techniques. A given polarization state can be due to a specific emission mechanism, reprocessing events, magnetic fields, or even relativistic effects in the source. The polarization behavior across emission and absorption lines can be particularly insightful due to the drastic but systematic change of opacity across a narrow spectral range and possible resonant line scattering. To interpret spectropolarimetric data, detailed radiative transfer modeling is necessary. In this lecture I point out some important polarization results that were obtained in various areas of astrophysics and that illustrate how to exploit different polarization mechanisms. Then, I describe the radiative transfer code STOKES that is being developed at Strasbourg University. The code enables spectral and polarization modeling across a broad spectral range reaching from the optical to the X-ray band. Due to its Monte-Carlo approach, STOKES enables 3D radiative transfer and takes into account variability effects. While it was designed for research on active galactic nuclei, the code is rather versatile and can be applied to other astrophysical areas. I am going to show a few examples of STOKES modeling of intensity and polarization spectra as well as polarization images. A basic version of the code is publicly available at http://www.stokes-program.info/ and will be upgraded shortly.

## CONSTRAINING SUB-ORBITAL STRUCTURES IN AGN ACCRETION DISKS FROM POLARIZED BROAD EMISSION LINES

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Understanding the physics of the accretion flow around black holes remains an important challenge. In the so-called thermal state the bulk of the bolometric luminosity is produced in an accretion disk. The theory of such a disk is based on the very successful, while phenomenological alpha-prescription and assumes that the disk properties do not vary with azimuth. Nonetheless, X-ray observations of a few bright Seyfert-1 galaxies suggested significant energy dissipation in very localized, active regions (hot spots). Support for such a picture also comes from (GR-)MHD modeling of the inner accretion flow. Gaskell (2010) suggested that off-axis dissipation of energy is important also at larger disk radii where the optical/UV continuum is produced. I present radiative transfer modeling for various off-axis irradiation scenarios and show that they explain characteristic variations of the polarization degree and position angle across broad emission lines. Implications of the model for the broadband spectrum are discussed and compared to spectropolarimetric observations of several Seyfert galaxies. I illustrate how polarization variability can discriminate the off-axis model from previous interpretations that are based on axis-symmetric scattering. A main goal of this work is to constrain the fraction of the accretion energy that is transformed into continuum radiation by an off-axis source and to thus provide new observational constraints for accretion models.

## COST ACTION MP1104 "POLARIZATION AS A TOOL TO STUDY THE SOLAR SYSTEM AND BEYOND"

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COST (European Cooperation in Science and Technology) is one of the longest-running European frameworks supporting cooperation among scientists and researchers across Europe. It does not fund science (salary, hardware, ...) but foster collaborations between otherwise fragmented communities. Our COST Action MP1104 "Polarisation as a tool to study Solar System and beyond" aims at promoting polarisation as an invaluable tool to obtain a wealth of information about astrophysical bodies in our Solar System and beyond. The structure and main goals of our COST Action will be presented as well as important tools COST provides us for networking.

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# POLARISATION OF AURORAL RED LINE IN THE EARTH'S UPPER ATMOSPHERE: A REVIEW

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Polarisation of light is a key observable to provide information about asymmetry or anisotropy within a radiative source. Polarimetry of auroral emission lines in the Earth's upper atmosphere has been overlooked for decades. However, the bright red auroral line ($\lambda$ 6300Å) produced by collisional impact with electrons precipitating along magnetic field lines is a good candidate to search for polarisation. This problem was investigated recently by Lilensten et al (2006) and observations were obtained by Lilensten et al (2008), Barthélemy et al (2011) and Lilensten et al (2012) with a photopolarimeter. Analysis of the data indicates that the red auroral emission line is polarised at a level of a few percents. The results are compared to theoretical predictions of Bommier et al (2011) that were obtained for a directive impact. The comparison suggests the existence of depolarization due to the beam anisotropy loss by interaction with the ionosphere. The modeling is in progress. A new dedicated spectropolarimeter currently under development will also be presented. This instrument will cover the optical spectrum from approximately 400 to 700 nm providing simultaneously the polarisation of the red line and of other interesting auroral emission lines such as $N_2^+$ 1NG ($\lambda$ 4278Å), other $N_2$ bands, etc... The importance of these polarisation measurements in the context of atmospheric modelling and geomagnetic activity will be discussed.

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# POLARIMETRIC SHAPES OF SPECTRAL LINES IN SOLAR OBSERVATIONS

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A century has elapsed since the first observation of the polarimetric profile of a line of the solar spectrum. Since then, dramatic progress has been made in the instrumentation, which is now reaching unprecedented levels of sensitivity in the measurement of polarization signals in solar spectral lines. At the same time, the theoretical framework needed for the interpretation of polarimetric observations has steadily evolved from the pioneering methods, based on simple formulae, to the sophisticated structure that is nowadays used with success in the interpretation of solar observations. The present paper is intended to give an historical perspective of the evolution of this research field and of its major achievements, with particular emphasis on the role played by the magnetic field and by other physical agents in determining the polarimetric shapes of spectral lines.

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# ON THE IMPORTANCE OF X-RAY POLARIMETRY IN THE DIAGNOSIS OF THE IRON K$\alpha$ APPARENT BROADENING MECHANISM IN AGNs AND BHXRBs

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While being of different scales, the innermost regions of Active Galactic Nuclei (AGN) behave similarly to Black Hole X-ray Binaries (BHXRB), where reflection onto accretion disc produces fluorescent emission. In some bright Seyfert-1 galaxies and galactic black hole systems, the emitted iron line appears to be broadened by general gravity effects and is used to constrain the black hole spin. However, the interpretation of the line's extended red wing is actually a matter of debate. On the one hand side, it is believed that the line is due to reflection and reprocessing of X-ray photons in parts of the accretion disk that reach down to the innermost stable orbit (ISCO). In this case, the line enables us to probe the Keplerian motion in the direct vicinity of the black hole. Assuming that the disk and its irradiation are indeed truncated at the ISCO, the line thus puts important constraints on the black hole spin. On the other hand, the broad iron line has also been explained by absorption processes in a partially covering outflow that is located on the line of sight. In this case the curvature of the line's red wing would be much less connected to the black hole spin. A spectral and even a timing analysis of currently available, high-quality X-ray data of bright Seyfert galaxies and BHXRB may not solve the debate. Here we theoretically explore to which extend an X-ray polarization measurement in the iron line band of MCG-6-30-15 could help to resolve the issue. We apply STOKES, a multi-wavelength radiative transfer code that includes polarization to produce a set of absorption models. Assuming various configurations of the wind, we estimate the degree and position angle of X-ray polarization induced by (multiple) scattering inside the outflow and compare it to the polarization signature of relativistic reflection models. We thereby put constraints on the reflection and absorption geometries that allow a distinction between the two scenarios by the means of X-ray polarimetry.

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# SCATTERING LINE POLARIZATION FROM ILLUMINATED DISK-LIKE OBJECTS

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Multidimensional radiative transfer modeling has become necessary in order to properly model emerging line radiation from various astrophysical objects. Scattering polarization (i.e. Stokes Q and U) is even more sensitive to multidimensionality and geometry of the medium then the radiation intensity. Here we present two-dimensional approach to modeling of the astrophysical disks. For objects which are axially symmetric, 2D cylindrical geometry successfully replaces 3D Cartesian geometry, thus saving lot of computing time and memory. We solve unpolarized part of the computation via standard Jacobi iteration, used with the short characteristics method of formal solution. Polarized part is solved by switching to reduced intensity basis and performing lambda iteration for polarized part only. We apply our code to several models of circumstellar and accretion disks and discuss potential diagnostics capabilities of modeling spectral line polarization from these objects.

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# COLLISIONAL LINE BROADENING VERSUS COLLISIONAL DEPOLARIZATION: SIMILARITIES AND DIFFERENCES

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Within the impact approximation, collisional line broadening parameters and depolarizing and polariza-tion transfer rates are complementary: both include the effect of collisional transitions between the Zeeman sublevels of a given level, or between fine or hyperfine structure levels of a given term. However, there are several dierences: in line broadening, the two levels connected by the radiative transition contribute to the broadening, and also an interference term, whereas only one level or two close levels are concerned in the depolarization. Another difference lies in the fact that purely elastic collisions contribute also to the line broadening, whereas they do not contribute to the depolarization. The nature of these two kinds of coefficients will be recalled at the Conference. Then we will discuss the possibility to find some relationships or systematic trends concerning depolarization versus collisional broadening. This is to answer some current questions which come from the polarization community.

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# SELF-CONSISTENT POLARIZED RADIATIVE TRANSFER: CONNECTING THEORY AND OBSERVATIONS

**J. Stepan**

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Astrophysical objects are rarely observed with sufficient spatial resolution. Consequently, the detected spectra originate in different parts of these objects under different physical conditions and it is, in general, impossible to infer a finite set of thermodynamical quantities (temperature, pressure, ...) defining the system. Such a correspondence would typically be impossible even if observations with infinite spatial resolution were available because (1) the matter is often out of local thermodynamical equilibrium, and (2) the observed spectrum is a superposition of radiation emitted by atoms along the line of sight, which is sampling various physical conditions. Even though direct inversion of the physical quantities is often mathematically ill defined, comparison of the observations with sufficiently realistic models may provide suitable diagnostics. Multiple processes contribute to creation and modification of emergent spectral line polarization (anisotropic illumination, collisions, magnetic fields, ...). Moreover, the state of matter at different points of the plasmas is non-linearly coupled by radiation transfer. Resonance scattering polarization, which is sensitive to departures from local thermal equilibrium and to the anisotropies present in the system, carries an information on such processes encoded in the four Stokes parameters. The modeling and simulations provide a connection between the theory and observations: from the knowledge of elementary physical processes it is used for interpretation of the observational data from spatially complex plasma structures. The aim of polarized radiative transfer calculations is to find additional constrains to the models of such systems and to disentangle the above mentioned processes. I will briefly review the processes involved in non-LTE polarized radiative transfer problem and I will show how the self-consistent solutions do provide a clue for quantitative plasma diagnostics.

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# MoCA: A MONTE CARLO CODE FOR ACCRETION IN ASTROPHYSICS - THE IRON LINE POLARIZATION CASE

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The X-ray spectrum observed in X-ray Binaries (XRBs) and Active Galactic Nuclei (AGN) is complex and constituted by several components, due to the circumnuclear material which scatters, absorbs and reprocesses photons produced by the disc. A common feature in all XRBs and AGN X-ray spectra is a strong Iron K? emission line at 6.4 keV. The line is produced by the reprocessing of X-ray photons absorbed by the neutral disc. These lines often show a broad energy profile and the origin of this broadening is still matter of debate. The two common interpretations are that it is given either by General Relativistic effects or by Comptonization (or, of course, by a combination of the two). One way to discriminate between these explanations is given by the polarization signal. In the case of Comptonization, in fact, some degree of linear polarization is expected to be measured in the line flux while for GR broadening it is not predicted.

In the framework of this scenario we developed MoCA, a code dedicated to the study of the spectrum and the polarization signal produced in accreting sources. We are going to show some results on the Iron line case.

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# METHOD FOR SOLAR OXYGEN ABUNDANCE DETERMINATIONS FROM STOKES-V OBSERVATIONS OF THE QUIET SUN MAGNETIC ELEMENTS

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Oxygen is the third most abundant element in the Universe. However, there is only few possible spectral lines in the solar spectrum that can be used for the oxygen abundance determination, all of them are either formed under the conditions of the non-local thermodynamical equilibrium or blended by lines of other elements. That makes the solar oxygen abundance (SOA) determination particularly sensitive to the model atmosphere and atomic data. The use of the realistic 3D hydrodynamical models of the solar photosphere caused a downward revision of the abundance by a factor of 2 (Asplund et al, 2004). However, more recently, the SOA values measured by different groups using different methodologies showed a considerable scattering between the "old" (high) and the "new" (low) value.

A novel approach for the measurement of the SOA was proposed by Centeno and Socas-Navarro (2008). They used the wavelength shift and different sensibility to magnetic field of the Stokes-V profiles of the forbidden oxygen line at 6300 Åand the blending nickel line to evaluate the relative O/Ni abundance from spatially averaged sunspot observations. In this contribution we test a possible application of their method to spatially resolved observations of the quiet sun magnetic elements. An ad-hoc 3D model of the magnetic elements is obtained by inversion of the nearby Fe I 6302 Ålines. That model is then used to compute the O/Ni blend in Stokes-V that can be compared, pixel-by-pixel, to the simultaneous observation of that feature. We use snapshots from highly-realistic 3D radiative magnetohydrodynamics simulations to mimic such an observation with a telescope analogous to the SP/SOT onboard Hinode. The result of our test shows that this approach can provide a reliable value of the SOA. Moreover, through the spatial variation of the observed profiles, it provides additional information on the sensitivity of the O/Ni blend to the magnetic field, velocity, temperature and their relative abundance.

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# EXOPLANETARY SEARCHES WITH GRAVITATIONAL MICROLENSING: POLARIZATION ISSUES

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There are different methods for finding exoplanets such as radial spectral shifts, astrometrical measurements, transits, timing etc. Gravitational microlensing (including pixel-lensing) is among the most promising techniques with the potentiality of detecting Earth-like planets at distances about a few astronomical units from their host star. We emphasize the importance of polarization measurements which can help to resolve degeneracies in theoretical models. In particular, the polarization angle could give additional information about the relative position of the lens with respect to the source. Polarization can reach a few percent when a gravitational lens system consists of a star and an exoplanet while a source is a giant star in the Galactic bulge or in the Andromeda galaxy.

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