III WORKSHOP ON ACTIVE GALACTIC NUCLEI AND GRAVITATIONAL LENSING

October 7 - 11, 2014, Končarevo, Serbia

ABSTRACTS OF INVITED LECTURES AND PROGRAMME

Edited by Saša Simić, Luka Č. Popović and Milan S. Dimitrijević

Society of Astronomers of Serbia

Belgrade 2014

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SCIENTIFIC RATIONALE

Investigation of nature of the emitting ionized gas in galactic nuclei is one of important subjects in astrophysics today. Firstly, investigating the processes in the central parts of these objects, we can learn about the innermost parts of other 'normal' galaxies. Secondly, AGN are the most powerful sources, located at different cosmological time-scales, and their investigation is cosmologically important. Finally, a part of emission from these objects (e.g. in the X-rays) has its origin very close to a massive black hole, and investigation of this emission can help us understand the physical processes in a strong gravitational field. On the other side, a number of AGN are affected by gravitational lensing effect.

Gravitational lensing is in general achromatic: the deflection angle of a light ray does not depend on its wavelength. However, the wavelength-dependent geometry of the various emission regions may result in chromatic effect. Studies aimed at determining the influence of microlensing on spectra of lensed quasars (hereafter QSOs) ought to account for the complex structure of the QSO central emitting region. Since the sizes of the emitting regions are wavelength-dependent, microlensing by stars in a lens galaxy will lead to a wavelength-dependent magnification.

Many interesting details about the physics of processes that are taking place within AGN can be identified in the signal of their emitting regions (as e.g. Broad Line Region - BLR), but they suffer from a still missing complete picture of the complex kinematical and thermodynamical properties of the line emitting plasma. Since it is not yet possible to directly observe the spatial distribution of the broad line emitting medium, although many important achievements were obtained in the angular resolution of AGN cores at radio wavelengths, spectroscopic data are still the most useful way to investigate physics within the central part of an AGN.

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ПРЯМЫЕ ИЗМЕРЕНИЯ ТИПА ДВИЖЕНИЙ В BLR ДИСКАХ В СЕЙФЕРТОВСКИХ ГАЛАКТИКАХ НА ОСНОВЕ СПЕКТРОПОЛЯРИМЕТРИЧЕСКИХ НАБЛЮДЕНИЙ

Виктор Афанасьев[1], Лука Попович[2]

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Приведены результаты спектрополяриметрии семи сейфертовских галактик - 3C273, NGC4051, Akn 120, Mkn 6, NGC4151, NGC3227 и Mkn6 – у которых измерены размеры пылевого тора. Галактики наблюдались на 6-м телескопе при помощи прибора SCORPIO-2. Показано, что в рамках простой модели экваториального рассеяния (Смит и др., MNRAS) по наблюдаемой зависимости угла плоскости поляризации от длины волны в широкой линии $H\alpha$ можно определить зависимость радиальной скорости $V(R)\sim R^{\alpha}$ в диске от радиуса R на масштабах 0.1-0.2 пк. Для всех наблюдаемых объектов значение α оказалось приблизительно равным -0.5 с ошибкой 0.05-0.1, что указывает на кеплеровские движения облаков, излучающих в BLR, вокруг центральной сверхмассивной черной дыры. Определенные массы SMBH с учетом размера пылевого тора и фактора, определяемого наклоном диска, находятся в удовлетворительном согласии с определениями масс методом ревебрации.

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EXPLORATION OF THE BROAD LINE REGION GAS DYNAMICS OF SEYFERT GALAXIES USING SPECTRO-POLARIMETRIC OBSERVATIONS

Victor Afanasiev[1] and Luka Č. Popović[2]

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We present results of the spectro-polarimetric investigation of six Seyfert galaxies - 3C273, NGC4051, Akn 120, NGC4151, NGC3227 and Mkn6. Galaxies have been observed wit the 6-m telescope using the instrument SCORPIO-2. Using a simple model of the equatorial scattering (Smith et al, MNRAS) and estimated the inner size of the dusty torus we explore the dynamics of the gas in the BLR of these galaxies. We found that the radial velocity in the line profile is depending from the disk radius as log(V (R))=a+b*log(R), where b is approximately equal -0.5 with error 0.05-0.1, indicating the Keplerian motion of emitting clouds in the broad line region (BLR). Using estimates for the inner radius of the dusty torus we estimate that the outer radius of the Keplerian disc (or BLR) has an order of 0.1-0.2 pc. Moreover, we estimated masses of black holes which are in a good agreement with ones estimated by reverberation method.

SPECTRO-POLAROMETRIC VARIABITLITY OF RADIO-LOUD AGN 3C390.3

Victor L. Afanasiev[1], Alla I. Shapovalova[1] and Luka Č. Popović[2]

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Here we present results of four year (2010-2014) spectro-polarometric monitoring of radio-loud active galaxy 3C390.3. The galaxy has been observed with 6-m telescope of SAO observatory using SCORPIO-2 instrument with spectral resolution of 7-10 A in the spectral range between 4000 A and 7500 A. The interstellar polarization has been corrected using a number of starts projected nearby 3C390.3.We found a lag of 6 ± 2 days between the polarized and non-polarized continuum at 5100 A. This lag is significantly smaller than one we found for Hb (60±7 days) and Ha (138 ± 40 days).

The received result specifies that observed polarization is defined possibly by transfer of radiation in an accretion disk and jet synchrotron radiation. In the Ha line spectral region there is a depolarization about 0.5% in the continuum.

The polarized Ha broad profile shows a blue shift around -1200 km/s. The lag of polarized light in the Ha line is 89 ± 7 days, that indicates emission of a component of gas in the BLR, which is moving toward an observer from the accretion disk. The dimension of this (additional to disk emission region) is around 1.5 smaller than the disk dimension. The obtained results from spectro-polarmetric observations are in a good agreement with results obtained from the long term spectral monitoring of 3C390.3.

CHEMISTRY IN PREGALACTIC SHOCKS: A STATE-TO-STATE APPROACH

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Shocks in pristine composition gas can held to cloud collapse and eventually to star formation. An accurate description of the chemical pathways for the formation and destruction of several species is necessary to catch the heat transfer phenomena and as a consequence the physics of the collapse itself. The chemistry of such physical conditions will be described, together with the cooling mechanisms enhancing the density growth and the temperature decrease. Non-equilibrium distribution functions for the internal degrees of freedom of the most relevant molecules will be described according to the results of state-resolved chemical kinetics.

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STARK BROADENING IN ASTROPHYSICS

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Broadening of spectral lines by collisions with charged particles - Stark broadening is considered and analyzed here, from the point of view of applications in astronomy. It is of interest especially for analysis and synthesis of hot star spectra, in particular in the case of white dwarfs and pre-white dwarf stars but also for A and B type stars. It is of interest even for cooler star atmospheres as e.g. Solar one. Namely, the influence of Stark broadening within a spectral series increases with the increase of the principal quantum number of the upper level and consequently, Stark broadening contribution may become significant even for the Rydberg lines in the Solar spectrum. It is also of interest for modelling and analyzis of sub photospheric layers. This broadening mechanism is also of significance for the research of neutron stars and the investigation of radio recombination lines from molecular and ionized hydrogen clouds.

Stark broadening parameters are also needed for a number of problems in astrophysics as the determination of the chemical composition of stellar atmospheres, stellar elemental abundances determination from equivalent widths of absorption lines, estimation of the radiative transfer through the stellar plasmas, especially in subphotospheric layers, and for opacity calculations. radiative acceleration considerations, nucleosynthesis research etc.

In this lecture it will be reviewed and discussed astronomical applications of Stark broadening, as well as the results of Stark broadening study in Serbia, relevant to astrophysical problems.

Additionally, organization of Stark broadening data in STARK-B database and FP-7 VAMDC (Virtual Atomic and Molecular Data Center) european project will be discussed.

RESOLVING THE UNRESOLVABLE - POLARIMETRY OF ACTIVE GALACTIC NUCLEI AT MULTIPLE WAVE BANDS

René Goosmann

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Optical and ultraviolet polarimetry has been vital to explore the inner geometry and the kinematics of Active Galactic Nuclei (AGN). The technique is complementary to mirco-lensing observations as it encodes geometry information of unresolvable sources. More recently, the wavelength range at which polarized light of AGN can give us an insight in the accretion and ejection flow around supermassive black holes has been extended to the infrared and the sub-mm bands. In the future, we hope to also have access to X-ray polarization measurements and thus to further narrow down the observational constraints on the inner parts of AGN. I am going to review the progress of AGN research made by polarimetry, both on the observational and on the modeling side, and I give prospects on future techniques and open questions that we hope to solve.

LONG-TERM OPTICAL SPECTRAL MONITORING OF AGN: THE PROPERTIES OF BLR GAS

A. I. Shapovalova[1], L. Č. Popović[2], D. Ilić[3], A. N. Burenkov[1], V. H. Chavushyan[4], A. Kovačević[3], W. Kollatschny[5] et al.

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Now, it is wide accepted that the nuclear activity of active galactic nuclei (AGNs) is due to accretion of the gas onto a supermassive black hole. The huge amount of energy released in the center of AGNs occurs very close to the central black hole (r <0.1pc), where the broad emission lines are emitted, in the so called the Broad Line Regin (BLR). The BLR is very compact and cannot be resolved by direct observations with big telescopes. Therefore, the BLR can be investigated by indirect methods, as e.g. using variability of broad lines and continuum. The broad line fluxes are changing in response to the continuum variability with time-lag since (the effect of light traveling) that gives the opportunity to investigate the physical and kinematical properties the BLR (so called reverberation method). Consequently, a long period spectro-photometric monitoring of AGNs is one of the main methods to study of the properties of the BLR gas using broad emission lines.

In this lecture we will describe the history of spectral observations of AGN in SAO RAS by method spectral and photometric monitoring and results obtained in cooperation with colleagues from other observatories. In 1996 at SAO a long-term monitoring program was launched for 10 AGNs, including mostly Seyfert galaxies, type Sy1-Sy 1.5 and QSOs. Spectral monitoring was carried with 1 m Zeiss and 6 m telescopes SAO RAS. Since 1998 monitoring camping started with the two 2.1 m teleskopes from Mexico (INAOE's 2.1 m telescope of the Guillermo Haro Observatory at Cananea, Sonora, and the 2.1 m telescope of the Observatorio Astronómico Nacional at San Pedro Martir, Baja California). Additionally,

since 2009 we used the archived observations obtained at the Calar Alto Observatory telescopes. During nearly 20 years of monitoring we obtained long series of spectra for 10 AGNs with duty cycle (frequency) about 1-2 times a month. At present, we have analyzed ~50% of the spectral data. We have investigated the variability of broad emission lines and continuum flux and profile variations of these lines during a long period and obtained some constrains for the geometrical and dynamical structure and physics of the BLR. Here we present some of the most interesting results of our spectral monitoring for five Seyfert galaxies.

GRAVITATIONAL LENSING IN THE STRONG GRAVITATIONAL FIELD: A CASE OF THE BLACK HOLE AT THE GALACTIC CENTER

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There are not too many astrophysical cases where one really has an opportunity to check predictions of general relativity in the strong gravitational field limit. For these aims the black hole at the Galactic Center is one of the most interesting cases since it is the closest supermassive black hole. Gravitational lensing is a natural phenomenon based on the effect of light deflection in a gravitational field (isotropic geodesics are not straight lines in gravitational field and in a weak gravitational field one has small corrections for light deflection while the perturbative approach is not suitable for a strong gravitational field).

Now there are two basic observational techniques to investigate a gravitational potential at the Galactic Center, namely, a) monitoring the orbits of bright stars near the Galactic Center to reconstruct a gravitational potential; b) measuring a size and a shape of shadows around black hole giving an alternative possibility to evaluate black hole parameters in mm-band with VLBI-technique. At the moment one can use a small relativistic correction approach for stellar orbit analysis (however, in the future the approximation will not be not precise enough due to enormous progress of observational facilities) while now for smallest structure analysis in VLBI observations one really needs a strong gravitational field approximation. We discuss results of observations, their conventional interpretations, tensions between observations and models and possible hints for a new physics from the observational data and tensions between observations and interpretations.

PROGRAMME

Tuesday, October 7
17:00 - 19:00 - Arrival and registration
19:00 - 20:00 - Welcome cocktail and dinner

Wednesday, October 8
Chairman: *Saša Simić*
9:45 - 10:00 - *Opening ceremony*
10:00 - 10:45 - **Viktor Afanasiev and Luka Č. Popović:** *Exploration of the BLR gas dynamics of Seyfert galaxies using spectro-polarimetric observations*
10:50 - 11:35 - **Alexander F. Zakharov:** *Gravitational lensing in the strong gravitational field: a case of the black hole at the Galactic Center*
11:40 - 13:00 - Discussion and work on mini projects
13:00 - 15:00 - Lunch break
15:00 - 15:40 - **Milan S. Dimitrijević and Zoran Simić:** *Stark broadening in astrophysics*
15:45 - 18:00 - Work on mini projects
19:00 - Dinner time

Thursday, October 9
Chairman: *Vladimir Srećković*
10:00 - 10:45 - **Carla Maria Coppola:** *Chemistry in pregalactic shocks: a state-to-state approach*
11:00 - 15:00 - Excursion with lunch
15:00 - 18:00 - Work on mini projects
19:00 - Dinner time

Friday, October 10
Chairman: *Predrag Jovanović*
10:00 - 10:45 - **Alla I. Shapovalova:** *Long-term optical spectral monitoring of AGN: The properties of BLR gas*
10:50 - 11:35 - **René Goosmann:** *Resolving the unresolvable - polarimetry of active galactic nuclei at multiple wave bands*
11:40 - 13:00 - Discussion and work on mini projects
13:00 - 15:00 - Lunch break

Chairman: *Dragana Ilić*
15:00 - 15:20 - **Wolfram Kollatschny:** *Broad line region structure in selected AGN*
15:20 - 18:00 - Work on mini projects
19:30 - Conference dinner

Saturday, October 11
Chairman: *Edi Bon*
10:00 - 10:45 - **Victor Afanasiev:** *Spectro-polarometric variabitlity of radio-loud AGN 3C390.3*
10:50 - 11:45 - Discussion and work on mini projects
11:45 - 12:00 - Closing ceremony
12:00 - 13:00 - Lunch time
13:00 - Departure to Belgrade

MINI-PROJECTS

MP1: Physics of the AGN emitting regions
MP2: Strong gravitation and centers of AGNs
MP3: AGNs and super-massive binary black hole systems: Spectral Energy Distribution (SED) and microlensing effect
MP4: Databases for investigation of the physics of AGNs
MP5: SDSS and LSST in AGN and GL investigations
MP6: Long-term spectral variability of AGNs
MP7: Polarization of the AGN spectra
MP8: Astrophysical plasmas

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