RAGtime 22

Monday 19 October 2020 - Friday 23 October 2020

Book of Abstracts

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Conference Opening

Author: Zdeněk Stuchlík[1]

[1] *Silesian University in Opava, Czech Republic*

Corresponding Author: zdenek.stuchlik@physics.slu.cz

Monday Afternoon / 11

Dynamical instability of polytropes in spacetimes with a cosmological constant

Author: Camilo Posada[1]

Co-authors: Jan Hladík [2] ; Zdeněk Stuchlík [3]

[1] *Silesian University in Opava*

[2] *Institute of Physics in Opava, Silesian University*

[3] *Silesian University in Opava, Czech Republic*

Corresponding Author: camilo.posada@physics.slu.cz

The dynamical instability of relativistic polytropic spheres, embedded in a spacetime with a repulsive cosmological constant, is studied in the framework of general relativity. We apply the methods used in our preceding paper to study the trapping polytropic spheres with Λ=0, namely, the critical point method and the infinitesimal and adiabatic radial perturbations method developed by Chandrasekhar. We compute numerically the critical adiabatic index, as a function of the parameter σ=pc/(ρcc2), for several values of the cosmological parameter λ giving the ratio of the vacuum energy density to the central energy density of the polytrope. We also determine the critical values for the parameter σcr, for the onset of instability, by using both approaches. We found that for large values of the parameter λ, the differences between the values of σcr calculated by the critical point method differ from those obtained via the radial perturbations method. Our results, given by both applied methods, indicate that large values of the cosmological parameter λ have relevant effects on the dynamical stability of the polytropic configurations.

AGNs and Supermassive Black Holes / 12

Acceleration capabilities of nearby supermassive black holes

Authors: Arman Tursunov[1] ; Zdeněk Stuchlík[2] ; Martin Kološ[3]

[1] *Silesian University in Opava*

[2] *Silesian University in Opava, Czech Republic*

[3] *Institute of Physics, Silesian University in Opava*

Corresponding Author: arman.tursunov@physics.slu.cz

Supermassive black holes (SMBHs) are among the most powerful energy sources in the Universe due to enormous energy stored in their spins. However, efficient extraction of this mechanical energy requires interactions of SMBHs with magnetic fields of external origin. In this talk I will discuss the role of black hole spin and magnetic field on the acceleration of charged matter for chosen 25

nearby SMBH candidates in relation to the ultra-high-energy cosmic rays, relativistic jets and hot-spots.

AGNs and Supermassive Black Holes / 15

Missing bright red giants in the Galactic center: A fingerprint of its once active state?

Authors: Michal Zajaček[1] ; Anabella Araudo[2] ; Vladimir Karas[3] ; Bozena Czerny[1] ; Andreas Eckart[4]

[1] *Center for Theoretical Physics, Polish Academy of Sciences*

[2] *ELI Beamlines, Institute of Physics, Czech Academy of Sciences*

[3] *Astronomical Institute, Czech Academy of Sciences*

[4] *First Institute of Physics, University of Cologne*

Corresponding Author: zajacek@cft.edu.pl

The observations in the near-infrared domain revealed that old bright late-type stars have a flat to a decreasing surface-density profile, which is in contrast to the cusp-like distribution of young OB/Wolf-Rayet stars. The core-like distribution of bright red giants is apparent from the decrease in the strength of the CO bandhead as well as from the stellar number counts. More recently, it was found that faint late-type stars exhibit a cusp-like distribution. Hence, a certain mechanism must have taken place that led to the preferential depletion of bright late-type stars, leaving fainter giants intact. Here we propose that the interactions of large red giants with the Galactic center nuclear jet during its active phases led to the effective ablation of bright late-type stars. Several thousand star-jet passages led to the drop in the infrared luminosity, which resulted in the flattening of the original cusp-like profile. The red giant - jet interactions were the most efficient within the inner ~0.04 pc (S cluster). On larger scales, the mechanism was complemented by the star-accretion disc collisions up to ~0.5 pc, while on the smallest milliparsec scales tidal stripping operated.

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Particle acceleration in the hotspot of radiogalaxy 3C 105

Author: Yelyzaveta Pulnova[1]

Co-author: Anabella Araudo [2]

[1] *ELI Beamlines; Institute of Theoretical Physics, Charles University*

[2] *ELI Beamlines, FZU - Institute of Physics of the Czech Academy of Sciences*

Corresponding Author: eliza.pulnova@gmail.com

The origin of Ultra High Energy Cosmic Rays is still unknown, and Active Galactic Nuclei (AGN) have been proposed as candidates to accelerate these particles. The aim of our work is to test the model of the particle acceleration in the hotspots of the AGNs. Using the multi-wavelength data of radiogalaxy 3C 105 S we calculate the maximum achievable energy of the cosmic rays through via the diffusive-shock acceleration (DSA) mechanism. We consider that the magnetic field in the jet termination region (hotspot) is amplified by the Bell instabilities. We find that maximum energy hat particles can achieve in the hotspots of radiogalaxy 3C 105 is well below the energy of Ultra High Energy Cosmic Rays.

Modelling of Accretion Flows I / 19

Jet variability properties of gamma ray bursts

Authors: Bestin James[1] ; Agnieszka Janiuk[2]

[1] *Center for Theoretical Physics, Polish Academy of Sciences*

[2] *CTP PAS*

Corresponding Author: bestin@cft.edu.pl

Different types of astrophysical black hole sources show variable accretion flows. They are found in gamma ray bursts, active galactic nuclei and radio loud objects such as blazars. These objects often have relativistic jets pointing at a small angle from our line of sight. Observational studies have found correlations between the minimum variability time-scale and Lorentz factor for these sources. The variability of the inflow can be transmitted to the outflow properties. Motivated by the observational properties of black hole sources, the accretion inflow and outflow properties are investigated by numerical GR MHD simulations.

Modelling of Accretion Flows I / 30

Accretion induced black hole spin up revised by numerical GR MHD simulations

Author: Agnieszka Janiuk[1]

Co-author: Dominika Król [2]

[1] *CTP PAS*

[2] *Jagiellonian University and CTP PAS*

Corresponding Authors: agnes@cft.edu.pl, dominika.krol896@gmail.com

We investigate the accretion induced spin up of the black hole via numerical simulations. Our method is based on general-relativistic hydrodynamics of the slowly-rotating flows in the Kerr metric. We account for the changing black hole mass and spin during accretion. We study non-magnetized flows with shocks, and finally, we also include magnetic field endowed in the gas. The aim of this study is to verify whether the high mass black holes maybe produced with large spins, even though at birth the collapsars might have contained non-spinning,or moderately-spinning cores. In this way, we put constraints on the content of angular momentum in the collapsing massive stars.

Modelling of Accretion Flows I / 35

Modeling of Wind -fed accretion in HMXBs using GRMHD code

Authors: Ishika Palit[1] ; Agnieszka Janiuk[2] ; Bozena Czerny[3]

[1] *Center for theoretical physics PAS*

[2] *CTP PAS*

[3] *Center for Theoretical Physics*

Corresponding Author: ishi2694@gmail.com

Accretion disks in High mass X-ray binaries (HMXB's) are mostly fed by the stellar wind from their companion star. These winds also affect the observed X-ray spectra arising from the hot coronal

flow.
Cygnus X-1 and its companion star, HDE-226868 is one of such HMXBs. It is one of the brightest X-ray sources observed and shows the X-ray intensity variations in both the soft and hard X-rays. I will present my recent work on 2D numerical modeling using GRMHD code - HARM, replicating such focused, clumpy wind from the binary companion fed for accretion onto the black hole. We model an inviscid, non-magnetized, transonic accretion flow with a low angular momentum profile. I will talk about how we model transonic accretion and my prescribed time-dependent boundary conditions in this code. I will further discuss how it affects the hydrodynamics of the flow in the relativistic framework and what information it reflects on the Power Density Spectra (PDS)

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The effective potential in Newton's, Einstein's theories and beyond

Author: Marek A. Abramowicz[1]

[1] *CAMK, Poland, Silesian University in Opava, Czech Republic, Göteborg University, Sweden*

Corresponding Author: marek.abramowicz@physics.gu.se

I shortly describe the concept of the effective potential in Newton's theory and claim that even if one does not know Einstein's general relativity, one may correctly guess the topology of the potential in Einstein's theory from Newton. This allows one to discover, without Einstein's equations, all "relativistic effects" in particles' and photons' motion around compact objects in the strong field limit. I speculate that the same may be true for quantum effects in strong gravity: even without knowing Quantum Gravity (QG) theory, one may guess all classes of all the QG effects, potentially observable in particles' and photons' motion around compact Quantum Gravity objects. This may be relevant for interpreting the EHT images (in particular secondary rings) and the LIGO-Virgo results (in particular ringdowns and echoes).

Advanced Computational Methods in Astrophysics / 13

Training a Machine Learning Classifier to Predict Quasar Photometric Redshifts

Author: Enda Farrell[1]

[1] *Nicolaus Copernicus Astronomical Center (CAMK)*

Corresponding Author: efarrell@camk.edu.pl

In the era of massive all-sky surveys, calculating spectroscopic redshifts (Spec-Z) is time-consuming and costly. Instead, broadband photometry may be used as a proxy for spectrographic measurements. We train an off-the-shelf classifier to estimate photometric redshifts (Photo-Z) from SDSS Quasar imaging data. We outline the technique of cross-validation to reduce bias and variance in the model and improve calibration. Reasons for so-called catastrophic prediction failures are discussed and popular packages such as *scikit-learn* and *AstroML* examined. The modern Deep Learning package 'fastai' is introduced along with a survey of Neural Net (NN) approaches. Despite Machine Learning being something of a dark art, surprisingly useful results may be extracted using modern software packages.

Advanced Computational Methods in Astrophysics / 24

Deterministic Aspect of the γ-ray Variability in Blazars

Author: Radim Panis[1]

Co-authors: Gopal Bhatta [2] ; Zdeněk Stuchlík [1]

[1] *SLU Institute of physics*

[2] *Jagelonian University*

Corresponding Author: panis.r@gmail.com

Linear time series analysis, mainly the Fourier transform based methods, has been quite successful in extracting information contained in the ever-modulating light curves (Lcs) of active galactic nuclei, and thereby contribute in characterizing the general features of supermassive black hole systems. In particular, the statistical properties of γ-ray variability of blazars are found to be fairly represented by flicker noise in the temporal frequency domain. However, these conventional methods have not been able to fully encapsulate the richness and the complexity displayed in the light curves of the sources. In this work, to complement our previous study on the similar topic, we perform non-linear time series analysis of the decade-long Fermi/LAT observations of 20 γ-ray bright blazars. The study is motivated to address one of the most relevant queries that whether the dominant dynamical processes leading to the observed γ-ray variability are of deterministic or stochastic nature. For the purpose, we perform Recurrence Quantification Analysis of the blazars and directly measure the quantities which suggest that the dynamical processes in blazar could be a combination of deterministic and stochastic processes, while some of the source light curves revealed significant deterministic content. The result with possible implication of strong disk-jet connection in blazars could prove to be significantly useful in constructing models that can explain the rich and complex multi-wavelength observational features in active galactic nuclei. In addition, we estimate the dynamical timescales, so called trapping timescales, in the order of a few weeks.

Modelling of Accretion Flows III / 23

From gappy to ringed: signatures of the accretion disk radial structure in profiles of the reflection line

Author: Marcel Štolc[1]

Co-authors: Michal Zajaček [2] ; Vladimír Karas [1]

[1] *Astronomical Institute, Czech Academy of Sciences*

[2] *Center for Theoretical Physics, Polish Academy of Sciences*

Corresponding Author: stolcml@gmail.com

The standard scenario of a geometrically thin, planar accretion disk can be violated by a number of effects that must operate in astrophysically more realistic schemes. Even within a highly simplified framework of an axially symmetric (2D), steady, Keplerian accretion, the radial structure can be different from the predictions of the classical Shakura-Sunyaev theory. For example, stars and stellar-mass black holes can be embedded within the accretion disk, where they may induce formation of gaps in the radial density profile. Also, an intermittent supply of gas may lead to individual accretion rings rather than an extended disk. In this contribution we focus on the theoretical profiles of the spectral line produced by reflection of the surface of both gappy accretion disk and ring-like structure residing near a black hole. While the smooth accretion disk leads to a typical, double-horn shape with unequal wings due to Doppler boosting and an additional peak due to the lensing amplification, gaps and rings give rise to a more complex dependence which reflects the location and the radial extent of the inhomogeneities in the accretion flow.

Modelling of Accretion Flows III / 17

Magnetically Ejected Disks: Equatorial Outflows Near Vertically Magnetized Black Hole

Author: Vladimír Karas[1]

Co-authors: Kostas Sapountzis [2] ; Agnieszka Janiuk [2]

[1] *Astronomical Institute, Czech Academy of Sciences*

[2] *Center for Theoretical Physics, Polish Academy of Science*

Corresponding Author: vladimir.karas@asu.cas.cz

Black holes attract gaseous material from the surrounding environment. Cosmic plasma is largely ionized magnetized because of electric currents flowing in the highly conductive environment near black holes; the process of accretion then carries the magnetic flux onto the event horizon, $r \simeq R_+$. On the other hand, magnetic pressure acts against accretion. It can not only arrest the inflow but it can even push the plasma away from the black hole if the magnetic repulsion prevails. The black hole does not hold the magnetic field by itself. In this contribution we show an example of an equatorial outflow driven by a large scale magnetic field. We initiate our computations with an axially symmetric configuration of a uniform (Wald) magnetic field aligned with the common rotation axis of the black hole and the accretion disk. For the fluid distribution we assume a spherically symmetric (Bondi) accretion flow infalling initially onto the black hole from a large distance, $r \gg R_+$. Then we evolve the initial configuration in the force-free limit of a perfectly conducting fluid. We observe how the magnetic lines of force start accreting with the plasma while an equatorial intermittent outflow develops and goes on ejecting some material away from the black hole.

Modelling of Accretion Flows III / 14

Perturbation of the accretion flow onto supermassive black hole by a passing star

Author: Petra Suková[1]

Co-author: Vladimír Karas

[1] *ASU CAS*

Corresponding Author: petra.sukova@asu.cas.cz

The close neighbourhood of a supermassive black hole contains not only the accreting gas and dust but also stellar-sized objects like stars, stellar-mass black holes, neutron stars, dust-enshrouded objects, etc. These entities interact with the accreting medium and perturb the quasi-stationary configuration of the accretion flow. We investigate how the passage of a star can influence the black hole environment with GRMHD 2D and 3D simulations. We focus on the changes in the accretion rate as well as the emergence of outflowing blobs of plasma.

Particle Dynamic in Strong Gravity / 7

Radiative Penrose process: Energy Gain by a Single Radiating Charged Particle in the Ergosphere of Rotating Black Hole

Authors: Martin Kološ[None] ; Arman Tursunov[None] ; Zdeněk Stuchlík[1]

[1] *Silesian University in Opava, Czech Republic*

Corresponding Author:

We demonstrate an extraordinary effect of energy gain by a single radiating charged particle inside the ergosphere of a Kerr black hole in presence of magnetic field. We solve numerically the covariant form of the Lorentz-Dirac equation reduced from the DeWitt-Brehme equation and analyze energy evolution of the radiating charged particle inside the ergosphere, where the energy of emitted radiation can be negative with respect to a distant observer in dependence on the relative orientation of the magnetic field, black hole spin and the direction of the charged particle motion. Consequently, the charged particle can leave the ergosphere with energy greater than initial in expense of black hole's rotational energy. In contrast to the original Penrose process and its various modification, the new process does not require the interactions (collisions or decay) with other particles and consequent restrictions on the relative velocities between fragments. We show that such a Radiative Penrose effect is potentially observable and discuss its possible relevance in formation of relativistic jets and in similar high-energy astrophysical settings.

Particle Dynamic in Strong Gravity / 3

Acceleration of the high energy protons in an active galactic nuclei

Authors: Alexey Gunya[1] ; Yakov Istomin[1]

[1] *The P. N. Lebedev physical institute*

Corresponding Author: aagunya@lebedev.ru

Acceleration of the high energy cosmic rays protons in the active galactic nuclei is considered.

The major acceleration stage is the centrifugal acceleration in a magnetosphere of the central machine light cylinder surface. In the during to calculations, the received dependence of the maximum energy on the parameter of the magnetization and parameter of relation toroidal and poloidal magnetic fields led to the conclusion that achievement of a theoretical maximum limit of value L-factor isn't possible for the accelerated particle in the magnetosphere of a black hole due to restrictions of the topology of toroidal and poloidal magnetic fields imposed by features of the relation. The analysis of special cases of the relation of a toroidal and poloidal magnetic field showed what in the presence of the toroidal magnetic field which is significantly more poloidal (case AGN with jet) the maximum L-factor value reaches $\gamma_{max}^{2/3}$, in the case when toroidal field to become smaller in comparison to the poloidal field (case non-active galaxy nuclei) the maximum L-factor value doesn't exceed $\gamma_{max}^{1/2}$.

The relativistic jet is the finishing area of the high energy proton acceleration. Here acceleration is carried out generally with a radial electric field. During the calculations was discover 3 acceleration regimes. The untrapped regime occurring in the case of the proton acceleration from the initial L-factor from the magnetosphere $\gamma_{max}^{2/3}$ to the theoretical maximum L-factor γ_{max}. The proton starts near the jet axis and moves directly inside out of the jet surface. In this case dimensionless parameter of the electric field β significantly more than the parameter of the magnetic field α. In the case of the trapped regime, the proton acceleration occurring by moving along the jet with oscillations in the radial direction. In the case of a strong toroidal magnetic field proton preaccelerated in the magnetosphere are pressed to the jet axis and practically is not accelerated in the jet.
For a number of the active galactic nucleus, such as M87 the maximum values L-factor for accelerated protons for scenarios of existence or lack of a toroidal magnetic field were defined. For special cases, there was a defined value of the maximum energy of the protons accelerated in object Sgr. A* magnetosphere that was confirmed by the experimental data obtained on the massive HESS of Cherenkov telescopes. Also, for cases microquasar such as SS433 was calculated proton acceleration energy and derived the acceleration regime.

Particle Dynamic in Strong Gravity / 16

Particle acceleration, magnetic field amplification, and gamma-ray emission in protostellar jets

Author: Anabella Araudo[1]

[1] *FZU - Institute of Physics of the Czech Academy of Sciences & Astronomical Institute of the Czech Academy of Sciences*

Corresponding Author: anabella.araudo@eli-beams.eu

Synchrotron radio emission from non-relativistic jets powered by massive protostars has been reported, indicating the presence of relativistic electrons and magnetic fields of about 1 mG. We study diffusive shock acceleration and magnetic field amplification in protostellar jets with speeds between 300 and 1000 km/s. In this talk I will show that the magnetic field in the synchrotron emitter can be amplified by the non-resonant hybrid (Bell) instability excited by the cosmic-ray streaming. By combining the synchrotron data with basic theory of Bell instability we estimate the magnetic field in the synchrotron emitter and the maximum energy of protons and electrons. Protons can achieve maximum energies in the TeV range and emit gamma rays in their interaction with matter fields. The gamma-ray flux can be significantly enhanced by the gas mixing due to Rayleigh-Taylor instabilities. The detection of this radiation by the Fermi satellite in the GeV domain and the forthcoming Cherenkov Telescope Array at higher energies may open a new window to study the formation of massive stars, as well as diffusive acceleration and magnetic field amplification in shocks with velocities of about 1000 km/s.

Particle Dynamic in Strong Gravity / 32

Dynamics of charged and magnetized particles around cylindrical black holes immersed in external magnetic field

Authors: Bobomurat Ahmedov[1] ; Javlon Rayimbaev[1] ; Ahmadjon Abdujabbarov[1] ; Ugur Camci[2] ; Aleksandra Demyanova[1]

[1] *Ulugh Beg Astronomical Institute*

[2] *Roger Williams University,*

Corresponding Author: orxideya28@gmail.com

The motion and acceleration of an electrically charged and magnetized particle around a cylindrical black hole in the presence of an external asymptotically uniform magnetic field parallel to the z axis is investigated. We look at circular orbits around a central object and study the dependence of the most internal stable circular orbits (ISCO) on the so-called magnetic coupling parameters, which are responsible for the interaction between the external magnetic field and magnetized and charged particles. It is shown that the ISCO radius decreases with increasing magnetized parameter. Therefore, we also studied collisions of magnetized particles around a cylindrical black hole immersed in an external magnetic field, and showed that the magnetic eld can act as a particle accelerator near non-rotating cylindrical black holes.

Oscilations in Strong Gravity / 36

Oscillation modes of thick accretion disks using finite-elements calculations

Author: Jiri Horak[1]

[1] *Astronomical Institute ASCR, Prague*

Corresponding Author: hjirkoun@gmail.com

We will present results for oscillation modes of thick accretion tori in Kerr spacetime using finite-element numerical method. We will derive relativistic version of the Papaloizou-Pringle equation for disks with general angular momentum distribution. Then we focus on the case of constant angular momentum tori and compare our results with those previously found by analytic perturbation methods.

Oscilations in Strong Gravity / 46

Oscillations of non-slender tori in the Hartle-Thorne geometry

Author: Monika Matuszková[None]

Corresponding Author: monika.matuszkova@physics.slu.cz

We examine the influence of the quadrupole moment of slowly rotating neutron stars on the oscillations of non-slender accretion tori. We assume a perfect fluid, polytropic, constant specific angular momentum, non-selfgravitating torus and analytically calculate formulas for the oscillation frequencies. So far, these have only been studied in the Kerr geometry. We apply known methods for examining the properties of radial and vertical axisymmetric and non-axisymmetric (m = -1) epicyclic modes of oscillating accretion tori in the Hartle-Thorne geometry. Our results are valid within the accuracy of up to second order in the angular momentum of the neutron star and the first order in its quadrupole moment. These can be used to study the properties of relativistic compact objects through the low-mass X-ray binaries phenomenon commonly known as the twin-peak quasi-periodic oscillations.

Oscilations in Strong Gravity / 2

X-ray timing and mass of accreting compact objects

Corresponding Author: gabriel.torok@physics.slu.cz

We explore the influence of non-geodesic pressure forces that are present in an accretion disk on the frequencies of its axisymmetric and non-axisymmetric epicyclic oscillation modes. We discuss its implications for models of high-frequency quasi-periodic oscillations (QPOs) that have been observed in the X-ray flux of accreting black holes (BHs) and neutron stars (NSs). In particular, we discuss the implications for a model recently proposed in the context of neutron NS QPOs as a disk-oscillation-based modification of the relativistic precession model. This model provides overall better fits of the NS data and predicts more realistic values of the NS mass compared to the relativistic precession model. It also implies a significantly higher upper limit on the microquasar's BH spin. We show that there is an analytic formula that well reproduce the models predictions on the QPO frequencies. Our simple formula may be used along with the observed QPO frequencies to estimate the mass and spin of compact objects.

Shapes of Black Holes / 39

Monitoring M87* in 2009-2017 with the EHT

Author: Maciek Wielgus[1]

[1] *Black Hole Initiative, Harvard University*

Corresponding Author: maciek.wielgus@gmail.com

The Event Horizon Telescope (EHT) has recently delivered the first resolved images of M87*, the supermassive black hole in the center of the M87 galaxy. These images were produced using 230 GHz observations performed in 2017 April. Additional observations are required to investigate the persistence of the primary image feature—a ring with azimuthal brightness asymmetry—and to quantify the image variability on event horizon scales. To address this need, we analyze M87** data collected with prototype EHT arrays in 2009, 2011, 2012, and 2013. While these observations do not contain enough information to produce images, they are sufficient to constrain simple geometric models. We develop a modeling approach based on the framework utilized for the 2017 EHT data analysis and validate our procedures using synthetic data. Applying the same approach to the observational data sets, we find the M87* morphology in 2009–2017 to be consistent with a persistent asymmetric ring of ~40 μas diameter. The position angle of the peak intensity varies in time. In particular, we find a significant difference between the position angle measured in 2013 and 2017. These variations are in broad agreement with predictions of a subset of general relativistic magnetohydrodynamic simulations. We show that quantifying the variability across multiple observational epochs has the potential to constrain the physical properties of the source, such as the accretion state or the black hole spin.

Shapes of Black Holes / **29**

Strong gravitational lensing around Kehagias-Sfetsos compact objects surrounded by plasma

Author: Sudipta Hensh[1]

Co-authors: Jan Schee [2] ; Ahmadjon Abdujabbarov [3] ; Zdeněk Stuchlík [1]

[1] *Institute of Physics, Silesian University in Opava*

[2] *Institute of Physics, SIlesian University in Opava*

[3] *Ulugh Beg Astronomical Institute, Tashkent, Uzbekistan*

Corresponding Author: f170656@fpf.slu.cz

The effect of strong gravitational lensing in the vicinity of Kehagias-Sfetsos compact object surrounded by plasma is studied. We examined the effect of plasma as well as spacetime parameter on deflection of photon and magnification of image.

Shapes of Black Holes / **40**

Influence of tidal force and magnetic field generated by surrounded toroidal structure onto the black hole shadow

Author: Dmitriy Ovchinnikov[1]

[1] *Silesian University in Opava*

Corresponding Author: dmitriy.ovchinnikov@physics.slu.cz

We consider a simple model of a black hole surrounded by a toroidal structure and experiencing deformation due to magnetic field and the tidal force. For this system we construct the shadows of Preston-Poisson black hole, apply it to supermassive black hole M87* and compare it with the shadows of corresponding Schwarzschild and Kerr black holes. We find that for large deviation parameters related with magnetic field and the tidal force the shadow of Preston-Poisson black hole is clearly distinguishable from Kerr and Schwarzschild black holes provided the angular resolution of measurements is of order μarcsec.

Alternative Theories of Gravity / 20

ISCO as a tool to alternate the Kerr metric with the charged stringy black hole metric.

Author: Bakhtiyor Narzilloev[1]

[1] *Fudan university, Shanghai, China; Ulugh Beg Astronomical Institute, Tashkent, Uzbekistan*

Corresponding Author: 18110190125@fudan.edu.cn

We show that in some ranges of the charge parameters charged stringy black hole metric can provide the same ISCO as in the case of the well known Kerr metric for the test particles. Based on the idea that charge parameters of the stringy black hole metric can provide the same ISCO for the test particles it would be difficult to distinguish these two metrics if one relies on the observations that have a strong dependence on the ISCO radius. So, based on this idea we show that in the case of electrically charged stringy black hole the charge parameter can completely mimic the rotation parameter of the Kerr metric; black hole with magnetic charge can mimic the spin up to $a = 0.85$ for magnetic dipoles endowed with a magnetic dipole moment; and up to $a = 0.8$ for magnetic monopoles.

Alternative Theories of Gravity / 43

Stability of asymptotically de Sitter and anti-de Sitter black holes in 4D regularized Einstein-Gauss-Bonnet theory

Author: Marco Cuyubamba[1]

[1] *University of Oldenburg*

Corresponding Author: marcoance1624@gmail.com

The regularized four-dimensional Einstein-Gauss-Bonnet model has been recently proposed in [D. Glavan and C. Lin, Phys. Rev. Lett. \textbf{124}, 081301 (2020)] whose formulation is different of the Einstein theory, allowing us to bypass the Lovelock theorem. The action is formulated in higher dimensions (D>4) by adding the Gauss-Bonnet correction to the conventional Einstein-Hilbert action with a cosmological constant. The four-dimensional spacetime is constructed through dimensional regularization by taking the limit D⟶4. We find explicitly the parametric regions of stability of black holes for the asymptotically flat and (anti-)de Sitter spacetimes by analyzing the time-domain profiles for gravitational perturbations in both vector and scalar channels. In addition to the known eikonal instability, we find the instability due to the positive cosmological constant. On the contrary, asymptotically anti-de Sitter black holes have no other instability than the eikonal one.

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Collapse of two-dimensional spin-orbit coupled Bose-Einstein condensate

Author: Shukhrat Mardonov[1]

[1] *Ulugh Beg Astronomical Institute*

Corresponding Author: mshuxrat@gmail.com

A finite-size quasi-two-dimensional Bose-Einstein condensate collapses if the attraction between atoms is sufficiently strong. Here we present a theory of collapse for condensates with the interatomic attraction and spin-orbit coupling. We consider two realizations of spin-orbit coupling: the axial Rashba coupling and the balanced, effectively one-dimensional Rashba-Dresselhaus one. In both cases spin-dependent "anomalous" velocity, proportional to the spin-orbit-coupling strength, plays a crucial role. For the Rashba coupling, this velocity forms a centrifugal component in the density flux opposite to that arising due to the attraction between particles and prevents the collapse at a sufficiently strong coupling. For the balanced Rashba-Dresselhaus coupling, the spin-dependent velocity can spatially split the initial state in one dimension and form spin-projected wave packets, reducing the total condensate density. Depending on the spin-orbit-coupling strength, interatomic attraction, and initial state, this splitting either prevents the collapse or modifies the collapse process. These results show that the collapse can be controlled by a spin-orbit coupling, thus extending the domain of existence of condensates of attracting atoms.

Modelling of Accretion Flows II / 8

Beamed emission in accretion simulations of neutron star ULXs

Author: David Abarca[1]

Co-authors: Kyle Parfrey [2] ; Włodek Kluźniak [3]

[1] *Nicolaus Copernicus Astronomical Center*

[2] *Princeton University*

[3] *CAMK*

Corresponding Author: dabarca@camk.edu.pl

We perform global 2D axisymmetric general relativistic radiation magnetohydrodynamic simulations of super-critical disk accretion onto a neutron star with a modest dipolar magnetic field strength of 20 GigaGauss as a model of a ULX. We study the effect of the boundary condition on the structure of the accretion column, outflow, and radiative output. In addition to fully absorbing and reflecting boundary conditions, we introduce a parameterized energy-reflecting boundary condition which returns the inflowing energy as radiative flux scaled by an albedo. We measure apparent isotropic luminosities ranging from 150-500 Eddington luminosities resulting from beaming of the radiation field by the accretion column.

Modelling of Accretion Flows II / 9

Flux ropes in SANE disks

Author: Miljenko Cemeljic[1]

[1] *NCAC, Poland & ASIAA, Taiwan*

Corresponding Authors: miki@camk.edu.pl, ,

In our 3D numerical simulations of accretion disk around a supermassive black hole with the GRMHD code Athena++, we follow the time evolution of magnetic field. In the case of SANE configuration, with multiple loops of oppositely directed initial poloidal magnetic field in the torus around a black hole, we follow the forming of flux ropes atop the disk, and their release into corona.

Modelling of Accretion Flows II / 10

Variability in accretion flows: Comparison of numerical simulations with observations

Author: Deepika Bollimpali[1]

Co-authors: Wlodek Kluzniak [2] ; Chris Fragile [3] ; Chris Done [4] ; Ramesh Narayan [5] ; Ra'ad Mahmoud ; Chris White [6]

[1] *Max Planck Institute for Astrophysics*

[2] *Nicolaus Copernicus Astronomical Center*

[3] *College of Charleston*

[4] *Durham University*

[5] *CfA Harvard*

[6] *KITP Santa Barbara*

Corresponding Author: ananda.depeika28@gmail.com

Long term observations of black-hole X-ray binaries show that these systems exhibit extreme, aperiodic variability on time scales of few milliseconds to seconds. The observed light-curves display various characteristic features like log-normal distribution and linear rms-flux relation, which indicates that the underlying variability process is stochastic in nature and is thought to be intrinsic to the accretion process. Theoretical models explain this variability as the inward propagating fluctuations of mass accretion rate on viscous timescales, although confirmations from the numerical simulations of magnetized accretion flows are required for a better understanding of the underlying variability process. Using a set of five exceptionally long general relativistic magnetohydrodynamic (GRMHD) simulations of geometrically thick, optically thin, black hole accretion flows as test-beds, we look for hints of propagating fluctuations of accretion rate in the simulation data. Indeed, our results from these simulations show evidence for the inward propagating fluctuations. Our further findings on how these results compare with the propagating fluctuations model and the observations will also be discussed.

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The presence of backflow in the simulated MHD disks

Author: Ruchi Mishra[1]

[1] *Camk*

Corresponding Author: rmishra@camk.edu.pl

We perform resistive MHD simulations of accretion disk with alpha-viscosity, accreting onto a rotating star endowed with a magnetic dipole. We find backflow in the presence of strong magnetic field and large resistivity, and probe for the dependence on Prandtl number. We find that in the magnetic case the distance from the star at which backflow begins, the stagnation radius, is different than in the hydrodynamic case, and shows non-stationary behavior.

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Conference photo

Turn on your camera and smile!

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Linear algebra and nonlinear diskoseismology

Author: Jiri Horak[1]

[1] *Astronomical Institute ASCR, Prague*

Corresponding Author: hjirkoun@gmail.com

In this talk we will introduce a new formalism to calculate nonlinear oscillations of fluids based on non-self-adjoint operators. The formalism is very intuitive, based on Eulerian description of perturbations and can be seen as an alternative to the standard Lagrangian approach used in the theory of nonlinear stellar pulsations. First we will review basic properties of nonlinear oscillations of systems having a single degree of freedom such as springs and pendulums and outline the method of multiple scales. We then move to continuous systems and outline our method. Finally, we apply it to nonlinear g-mode oscillations of thin accretion disks.

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Levitating atmospheres around naked singularities

Authors: Ronaldo Vieira[1] ; Wlodek Kluzniak[2]

[1] *Federal University of ABC, Brazil*

[2] *Nicolaus Copernicus Astronomical Center*

Corresponding Author: ronaldo.vieira@ufabc.edu.br

For a wide class of spherically symmetric naked singularities there is a sphere within which gravity is effectively repulsive. In such space-times accreting matter cannot reach the singularity and will instead form a levitating atmosphere, which is kept suspended by gravity alone. The density of the atmosphere has a maximum at a definite radius. In its properties the atmosphere is analogous to the recently discussed atmospheres that are are supported by radiation pressure above luminous neutron stars, however for the levitating atmospheres around a naked singularity no radiation need to be present.

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Global numerical simulations of geometrically thin accretion disks

Authors: Bhupendra Mishra[1] ; Wlodek Kluzniak[2] ; Chris Fragile[3] ; Mitch Begelman[4] ; Phil Armitage[5] ; Jake Simon[6]

[1] *LANL*

[2] *CAMK*

[3] *College of Charleston SC USA*

[4] *JILA University of Colorado Boulder*

[5] *CCA NY USA*

[6] *Iowa University Iowa USA*

Corresponding Author: mishra_b@lanl.gov

I will present results inferred from numerical study of geometrically thin accretion disk. The radiation-pressure dominated thin accretion disks undergo thermal instability which has been infamous for decades. We confirmed this instability in a 3D global radiative GRMHD simulation. In order to further understand thermal instability, we simulated GRHD models with \alpha-viscosity and concluded that radiation-pressure dominated thin disk always shows thermal collapse and no evaporation. However, we also argue based on our other global simulations that strong magnetic field could thermally stabilize the disk and show surface accretion. At the end, I shall also talk about time variability present in our GRHD models which show diskoseismic modes, vertical, radial and breathing oscillations. The time-variability found in our simulations could shed light on high-frequency quasi-periodic oscillations (QPOs) observed in low mass black hole X-ray binaries.

Compact Stars / **22**

The effect of magnetic field on the structure of strange quark stars

Author: Fatemeh Kayanikhoo[1]

[1] *CAMK*

Corresponding Author: f.kayanikhoo@gmail.com

Strange quark stars (SQS) are a possible type of compact objects, which remain after the end of the life of supermassive stars. After the first explosion of a massive star, if the density of matter in the core of the star increases to values above the nuclear saturation density, the quarks deconfine and a huge value of energy (1047 J) is released, leading to the second explosion that is super luminous and is called a Quark-Nova. The object, which remains after the Quark-Nova, would be a pure SQS. A promising candidate for the QN is Cassiopeia A.
The study of the SQS is an interesting subject for physicists and astrophysicists because they are systems of strange quark matter that can exist in extreme conditions (high enough density and temperature, and strong magnetic fields). Theoretical studies suggest that the magnetic field inside the compact objects (neutron stars and SQS) is ~1018 G. This strong magnetic field can affect the shape, mass, and radius of the compact objects.
In the current work, we study the effect of the strong magnetic field on the equation of state and the structure of SQS. We show that the maximum gravitational mass of the SQS increases with increasing the magnetic field. In addition, the results show that the star has an oblate shape under the effect of the strong magnetic field.

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Dense nuclear matter in the cores of neutron stars

Author: David Alvarez-Castillo[1]

[1] *Institute of Nuclear Physics PAS*

Corresponding Author: dalvarez@ifj.edu.pl

In this talk I will review and address the long standing problem of determination of the state of matter in the cores of neutron stars. Our understanding of the cold, dense nuclear matter in neutron star interiors has suffered a dramatic revolution during the recent years. On the one hand, laboratory experiments have been able to probe higher and higher densities that comprise the equation of state (EoS) of dense nuclear matter. On the other hand, multi-messenger astronomy observations have brought new physical constraints that narrow the parameter space of the different EoS models. There

is however, certain tension between astrophysical and terrestrial measurements. One practical way to implement all the available constraints is implementing a Bayesian analysis for model comparison, which I will present.

In order address the corresponding to state-of-the-art physics, I shall introduce different approaches to the neutron star EoS: pure hadronic stars, stars with hyperonic and condensate content, and hybrid stars whose cores supports deconfined quark matter as well as strange quark stars, for the sake of comparison. Moreover, I will emphasize the role of the nuclear symmetry energy in determination of the star properties, discuss the hyperon puzzle and present a particular model of hybrid stars: mass twins.

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Neutron-star crusts, mountains and gravitational waves

Author: John Miller[None]

Corresponding Author:

Abstract to follow

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Light ray as charge distinguisher of black holes in nonlinear electrodynamics

Author: Bobir Toshmatov[1]

Co-authors: Daniele Malafarina [2] ; Bobomurat Ahmedov [3]

[1] *Ulugh Beg Astronomical Institute, Tashkent*

[2] *Nazarbayev University, Nur-Sultan, Kazakhstan*

[3] *Ulugh Beg Astronomical Institute, Tashkent, Uzbekistan*

Corresponding Author: toshmatov@astrin.uz

It is well-known fact that a light ray does not follow the null geodesics of spacetime in nonlinear electrodynamics, instead it follows the null geodesics of so-called effective spacetime. Moreover, in general relativity coupled to the nonlinear electrodynamics the spacetime cannot possess both electric and magnetic charges at the same time. By combining these two phenomena, we aim to discover possibility whether it is possible to distinguish the type of charge of the spacetime, via the motion of light ray in it. The results show that if the spacetime is solution of general relativity coupled to the nonlinear electrodynamics, one cannot distinguish its type of charge (magnetic or electric) through the motion of light ray around it.

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Energetic Properties of Magnetized Neutron Stars in General Relativity

Author: Bobomurat Ahmedov[None]

Corresponding Author: bahmedov@yahoo.com

Observational properties and energetics of oscillating and rotating magnetized neutron stars will be discussed. A qualitative model for the explanation of the phenomenology of intermittent pulsars in terms of stellar oscillations that are periodically excited by star glitches has been proposed. The conditions for radio emission in rotating and oscillating magnetars, by focusing on the main physical processes determining when the magnetars may be radio-loud or radio-quiet will be discussed. The subpulse drift phenomena adopting the space-charge limited flow (SCLF) model and comparing the plasma drift velocity in the inner region of pulsar magnetospheres with the observed velocity of drifting subpulses is also explored. It is shown that the subpulse drift velocities would correspond to the drift of the plasma located very close or above the pair formation front. Moreover, a detailed analysis of PSR B0826-34 and PSR B0818-41 reveals that the variation of the subpulse separation with the pulse longitude can be successfully explained by the dependence of the plasma drift velocity on the angular coordinates.

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Dynamical analysis approaches in spatially curved FRW space-times

Authors: Morteza Kerachian[1] ; Giovanni Acquaviva[1] ; Georgios Loukes Gerakopoulos[2]

[1] *Charles University, Czech Republic*

[2] *Astronomical Institute, Czech Academy of Sciences*

Corresponding Author: kerachian.morteza@gmail.com

In this work we perform dynamical analysis of a broad classes of barotropic fluids and a non- minimally coupled real scalar fields in the Friedmann-Robertson-Walker (FRW) spacetime frame- work. The first part of our study concerns the dynamics of a fluid with an unspecified barotropic equation of state (EoS) having as the only assumption the non-negativity of the fluid's energy den- sity. The second part of our study concerns the dynamics of an unspecified positive potential in a spatially curved FRW spacetime. For each of these cosmological models we define a new set of dimensionless variables and a new evolution parameter. In the frameworks of these general setups, we have recognized several general features of these systems, like symmetries, invariant subsets and critical points, and provide their cosmological interpretation. The last part of our work provides some examples to show how these two general setups can be used.

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Accretion disks with radial heat advection

Authors: Michal Bursa[None] ; Radek Vavřička[None]

Corresponding Author:

The talk will discuss thermal solutions of a thin accretion disk model with magnetic fields and a radial gradient of entropy.

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Conference Closing

Corresponding Author: martin.urbanec@physics.slu.cz