Relativistic Fluids around Compact Objects

Monday, 5 May 2025 - Friday, 9 May 2025

CAMK

Book of Abstracts

Contents

Jets in accreting black-hole binaries 1

X-ray polarimetry as a tool to study the geometry of the emitting region in accreting black holes 1

General Relativistic Magnetohydrodynamic Simulations of Accretion Flows onto Merging Supermassive Black Holes 1

Multi-messenger Signals and Counterparts to Gravitational Waves 2

Diagnosing accretion with polarimetry 2

Radiation-mediated shocks in GRB prompt emission 2

Magnetospheres, jets and pulsed emission from compact objects 3

Dynamics of relativistic jet formation: case study of GRB 090510 3

Colliding Relativistic Shells: New Insights 4

Quantum kinetics of neutrinos in dense astrophysical environments 4

Collapsars: black hole properties, magnetic fields and r-process nucleosynthesis 5

Gamma-Ray Burst Jets in Circumstellar Material: Dynamics, Breakout, and Diversity of Transients 5

Accretion onto compact objects described by the Reissner-Nordström spacetime 5

Magnetar Evidence in Central Engines of Peculiar Gamma-Ray Bursts 6

Long timescale numerical simulations of large, super-critical accretion discs [online] . . 6

Acceleration and plunge near a rotating black hole 6

The structure of relativistic jets and their magnetic fields 7

Magnetic field dynamics in isolated neutron stars: insights from GRMHD simulations . . 7

Pseudo-Newtonian Simulations With Reissner–Nordström Naked Singularity 8

Exploring the Dynamics of Magnetically Arrested Disks: The Role of Radiative Cooling . 8

Do we understand pair cascade in AGN jets? 9

Radiative GRMHD simulations of sub-Eddington accretion: the Puffy disc 9

Energy flow and radiation luminosity in the simulations of neutron star Ultraluminous X-ray sources 9

cuHARM: general relativistic radiation magneto-hydrodynamics in the era of exascale computing 10

GRMHD simulations of accretion disks: QPOs, truncated disks and QPOs from truncated disks 10

Simulating a planet inside highly relativistic pulsar wind 11

Comparison of solutions with different pseudo-Newtonian potentials in numerical simulations of accretion disk around compact objects 11

Turbulence and magnetic configurations in neutron star interiors 12

MHD Simulations of Type I Bursts 12

Binary black holes in magnetized AGN disks 13

Machine Learning Enhanced Photometric Analysis of the Extremely Bright GRB 210822A 13

Identification of Extended Emission Gamma-Ray Burst Candidates Using Machine 14

Numerical Simulations of Supercritical Accretion Flows Around a Compact Object . . . 14

First Results from Spritz: A GRMHD Code for Binary Neutron Star Mergers with Microphysical Equation of State 15

3D geometry and magnetic connections of erupting black hole jet 15

Decoding M87's emission: A New Physically Consistent Model for Its Active Nucleus . . 16

Radiative model of MADs and its application to M87* 16

Numerical simulations of GRB jets from the BH horizon to post-breakout in collapsing stars 16

Impact of Self-Gravity on Jet Properties in Collapsar Models 17

Determining the role of irradiation in radiation pressure instabilities. 17

Numerical studies of relativistic jets from black holes 18

Simulations of hungry yet picky black holes [online] 18

Understanding Supernova Engines and the Properties of Compact Remnants [online] . . 18

Beyond the Kerr Black Hole-Torus paradigm 18

Radiation hydrodynamical simulations of super-Eddington mass-transfer in close BH binaries 19

Probing Radiation Pressure Instabilities in Neutron star LMXBs 19

Polarisation due to returning thermal disk radiation in the soft state of black-hole binaries 20

Today's Discoveries, Tomorrow's Frontiers: Multi-Messenger Astrophysics 20
Horizon-scale simulations of galaxy-fueled, strongly magnetized quasars 21
Cosmic Engines: How Black Holes Power the Brightest Objects in the Universe 21

Monday afternoon / **3**

Jets in accreting black-hole binaries

Author: Andrzej Zdziarski[None]

Corresponding Author: aaz@camk.edu.pl

The most spectacular jets are observed from active galactic nuclei, in particular from quasars. However, highly interesting jets are also launched by accretion flows in stellar binaries containing a normal star accreting onto a stellar-mass black hole. Such systems are analogs of quasars on a much smaller scale, and are called microquasars. There are two distinctly different types of jets in microquasars. Jets of the first type are steady, and are launched during accretion states characterized by hard X-ray emission. They are launched over weeks to months, but are observed only up to maximum distances of about a 1/1000 of a parsec. Those of the other type are launched on time scales of only a day during transitions of the accretion flow from the hard to soft spectral states, but are observed as moving blobs up to a parsec scale, i.e., up to ~1000 times larger distances. I will discuss possible causes of this difference, the jet emission mechanisms, collimation, the presence of electron-positron pairs, magnetic fields, bulk Lorentz factors and the jet power.

Tuesday afternoon / **4**

X-ray polarimetry as a tool to study the geometry of the emitting region in accreting black holes

Author: Juri Poutanen[1]

[1] *University of Turku*

Corresponding Author: juri.poutanen@gmail.com

The geometry of the X-ray emission region in accreting black holes has been a subject of debate for over three decades. Despite extensive spectral and timing data, no consensus has emerged on the structure of these regions. The launch of the Imaging X-ray Polarimetry Explorer (IXPE) at the end of 2021 marked a major advancement in X-ray astronomy, as it is the first satellite specifically designed to measure X-ray polarization. IXPE has provided two crucial pieces of information—polarization degree and polarization angle—that add new insights into the geometry of the emission regions around black holes.

In this talk, I will review the key discoveries made by IXPE, with a focus on accreting black holes in X-ray binaries. I will also highlight important results for supermassive black holes in Seyfert galaxies. Additionally, I will demonstrate how X-ray polarimetry has advanced our understanding of the complex emission region geometry in the peculiar X-ray binary Cyg X-3. By leveraging the unique capabilities of IXPE, we can now explore these systems in unprecedented detail, shedding new light on the fundamental processes that govern black hole accretion.

Tuesday morning / **5**

General Relativistic Magnetohydrodynamic Simulations of Accretion Flows onto Merging Supermassive Black Holes

Author: Bruno Giacomazzo[1]

[1] *University of Milano-Bicocca*

Corresponding Author: bruno.giacomazzo@unimib.it

I will present the results of our fully general relativistic magnetohydrodynamic simulations of accretion flows onto spinning supermassive black hole binary mergers. Supermassive binary black hole systems are formed after galaxy collisions and they are powerful sources of gravitational waves that will be detected by the future LISA mission. In our simulations we investigated the dynamics of the magnetized gas that may surround these systems during the last phases of inspiral, merger and post-merger. We studied systems with different black hole spin magnitudes and orientations in order to understand the effects of the black hole properties onto the electromagnetic counterparts that may be emitted.

Monday afternoon / 6

Multi-messenger Signals and Counterparts to Gravitational Waves

Author: Nicole Lloyd-Ronning[1]

[1] *Los Alamos National Lab*

Corresponding Author: lloyd-ronning@lanl.gov

In this talk, I will present the wide range of multi-messenger signals expected from gravitational wave (GW) sources across the frequency bands of all current and future GW detectors. I will begin at high frequency, discussing compact object binary mergers and massive stellar death. I will present some novel results on signatures expected from these latter events, which call into question our current understanding of heavy element production in our universe. I will then discuss the mid-frequency GW range, including potential fast radio bursts from extreme mass ratio inspirals, binary white dwarf mergers, and multi-messenger signatures from intermediate mass black hole binary mergers. We will proceed to the lowest frequency range, discussing supermassive black hole binary mergers and their corresponding counterparts. Finally, we will end with a brief discussion of the implications for future GW detectors and multi-messenger follow-up coordination, and how to optimize the physics we can glean from these extraordinary events.

Tuesday afternoon / 7

Diagnosing accretion with polarimetry

Authors: Maciek Wielgus[1]; Saurabh Saurabh[2]

[1] *Institute of Astrophysics in Andalusia, Granada, Spain*

[2] *Max Planck Institute for Radioastronomy, Bonn*

Corresponding Author: maciek.wielgus@gmail.com

Very long baseline interferometry observations can now resolve event-horizon angular scales for at least 2 supermassive black holes, M87*and Sagittarius A*. What is more, these observations give us access to resolved polarimetry, that constitute a particularly powerful tool for the diagnostic of the accretion flow and magnetic fields in the compact region. I will discuss how the polarization is used to analyze the Event Horizon Telescope (EHT) observations of M87*and Sagittarius A* in order to make comparisons between numerical models and the reality, and what constraints can be made on quantities such as the magnetic field strength and geometry or the temperature of the electrons.

Monday morning / 11

Radiation-mediated shocks in GRB prompt emission

Author: Felix Ryde[1]

Co-authors: Filip Alamaa [1]; Oscar Wistemar [1]

[1] *KTH*

Corresponding Author: fryde@kth.se

Gamma-ray bursts (GRBs) eject relativistic jets that are initially optically thick. The trapped radiation is released at the photosphere and could be responsible for the GRB prompt emission. For this to be feasible, subphotospheric dissipation should occur before the photons decouple from the plasma, with shocks being a likely dissipation mechanism. Due to the high radiation pressure, shocks below the photosphere are not collisionless but so called radiation-mediated shocks (RMSs), and the distinction is important for the resulting spectrum. In this talk, I present the first-ever fit of a prompt GRB spectrum with an RMS model. I also show that RMS spectra are in many ways similar to the observations, as they consist of a broad, soft power law across the sub-MeV-band with an additional break in X-rays. When synthetic spectra are fitted with a cutoff power-law function, we find that the catalogue distribution of low-energy slopes is naturally reproduced. Therefore, photospheric emission with properly modeled dissipation is a promising candidate for the prompt emission in GRBs.

Wednesday morning / 12

Magnetospheres, jets and pulsed emission from compact objects

Author: Oliver Porth[1]

[1] *Anton Pannekoek Institute for Astronomy, University of Amsterdam*

Corresponding Author: o.porth@uva.nl

The time-variable (in particular pulsed-) emission from black holes and neutron stars holds key information on the nature of curved spacetime and ultra dense nuclear matter. However, due to the complex plasma dynamics at play, the interpretation of the observed signals is difficult. I will present some recent work on modeling general relativistic magnetohydrodynamic processes around black holes. I will first discuss the dynamics of strongly perturbed black hole magnetospheres as they can occur for example during binary neutron star merger events. The simulations have revealed a brief 'black-hole pulsar' phase, followed by an intriguing alignment of the magnetic moment and black hole spin which can uniquely imprint the high energy emission of the current sheet. I will further discuss the transient dynamics of multipolar black hole magnetospheres which rapidly transition to a universal split-monopolar configuration.

:CFT Special seminar / 13

Dynamics of relativistic jet formation: case study of GRB 090510

Authors: Agnieszka Janiuk[None]; Joseph Saji[1]

[1] *CTP PAS*

Corresponding Authors: agnes@cft.edu.pl, jsaji@cft.edu.pl

We employ General Relativistic Magnetohydrodynamic (GRMHD) simulations to investigate the properties of GRB 090510, a short gamma-ray burst detected by Fermi-LAT. This study aims to quantify key parameters such as jet opening angles, energetics, Lorentz factors, and jet structures, alongside the progenitor details of the compact binary. Additionally, we perform a suite of models to study short GRB jet dynamics in general. Our results align closely with observations, validating our simulation methodology. This alignment enhances our theoretical models, improving their fidelity in replicating observed phenomena.

Monday morning / 14

Colliding Relativistic Shells: New Insights

Author: Jonathan Granot[1]

[1] *Open University of Israel*

Corresponding Author: granot.j@gmail.com

Shock waves are abundant in astrophysical sources, and are responsible for much of the electromagnetic emission that we observe from many sources. Therefore, the shock dynamics can significantly affect the observable signatures, and are important to account for when interpreting the observations. I will first discuss a planar collision between two cold shells, which may be relevant either for internal shocks within an outflow (e.g. in GRBs or AGN) or for an ejected shell colliding with a preexisting external shell (e.g. in magnetar giant flares, superluminous supernovae or possibly also in FRBs). Both the bulk velocity of the two shells and their relative velocity can range from Newtonian to ultra-relativistic, within the same formalism. The possible observable implications for prompt GRB emission from internal shocks will be outlined as an important case study, and the effects of a locally spherical geometry will be outlined. Finally, I will discuss an oblique collision between two cold shells, and its relation to the classical problem of shock reflection, as well as the conditions required for the production of a pair-annihilation line and its implications for the B.O.A.T, GRB 221009A.

Tuesday morning / 15

Quantum kinetics of neutrinos in dense astrophysical environments

Author: Hiroki Nagakura[1]

[1] *National Astronomical Observatory of Japan*

Corresponding Author: hiroki.nagakura@nao.ac.jp

Neutrinos play a crucial role in determining fluid dynamics and nucleosynthesis in core-collapse supernova (CCSN) and binary neutron star merger (BNSM). The neutrino kinetics which governs their transport in phase space, interactions with matter, and flavor conversions (or neutrino oscillations) is essential to develop realistic models of CCSN and BNSM. Accurate determination of neutrino radiation field involving neutrino flavor conversion requires solving quantum kinetic equation, but the numerical modeling is one of the formidable challenges in computational astrophysics. However, a remarkable progress has been made in the last few years. In this workshop, I will give an overview of the recent progress and discuss future perspectives towards incorporating effects of flavor conversions in CCSN/BNSM simulations.

Monday afternoon / 16

Collapsars: black hole properties, magnetic fields and r-process nucleosynthesis

Author: Ore Gottlieb[1]

[1] *CCA, Flatiron Institute*

Corresponding Author: oregottlieb@gmail.com

Collapsars are known to be the origin of GRB jets, black hole populations, and even potentially important r-process production sites in the early universe. In this talk, I will demonstrate how we can study the central engines of collapsars and jets, and establish the natal properties of their black holes. In particular, I will discuss how collapsar black holes acquire the strong magnetic fields necessary for powering long GRB jets, and the crucial role the magnetic field plays in determining the black hole properties and ejecting r-process ejecta from accretion disks to power collapsar kilnovae.

Monday morning / 17

Gamma-Ray Burst Jets in Circumstellar Material: Dynamics, Breakout, and Diversity of Transients

Author: Hamid Hamidani[1]

[1] *Tohoku University*

Corresponding Author: hhamidani@astr.tohoku.ac.jp

Recent observations indicate that stripped-envelope core-collapse supernovae are often surrounded by dense circumstellar material (CSM). Motivated by this, we develop an analytic model to systematically study the dynamics of long gamma-ray burst (LGRB) jet propagation in various CSM environments. We derive a general expression for the jet head velocity (β_h) and breakout time (t_b) valid across Newtonian, relativistic, and intermediate regimes, accounting for a previously unrecognized dependence on $1-\beta_\mathrm{h}$. Our results highlight a fundamental distinction between jet propagation in massive stars, where $\beta_\mathrm{h} \ll 1$, and in extended CSM, where $1-\beta_\mathrm{h} \ll 1$. We establish an analytic success/failure criterion for jets and express it in terms of jet and CSM parameters, revealing a strong dependence on CSM radius. To quantify the relativistic nature of the jet-cocoon system, we introduce the energy-weighted proper velocity $\overline{\Gamma\beta}$. We identify three possible jet outcomes—(a) successful jets ($\overline{\Gamma\beta} \sim 10-100$), (b) barely failed jets ($\overline{\Gamma\beta} \sim 1$), and (c) completely failed jets ($\overline{\Gamma\beta} \sim 0.1$) —and constrain their respective jet/CSM parameter spaces. We show that in (b) and (c), large CSM radii can result in luminous fast blue optical transients via cocoon cooling emission. This theoretical framework provides a basis for future observational and theoretical studies to understand the link between LGRBs, intermediate GRBs, low-luminosity LGRBs, and their environments.

Tuesday afternoon / 18

Accretion onto compact objects described by the Reissner-Nordström spacetime

Author: Tomasz Krajewski[1]

[1] *Institute of Fundamental Technological Research PAS*

Corresponding Author: tkrajewski@camk.edu.pl

We performed the first simulations of accretion onto the compact objects in the Reissner-Nordström (RN) space-time. The results could not be more different for the two cases. For a black hole, just as in the familiar Kerr case, matter overflowing the cusp plunges into the black hole horizon. For the naked singularity, the accreting matter forms an inner structure of toroidal topology and leaves the system via powerful outflows. The results obtained in general relativity are representative of those for spherically symmetric naked singularities and black holes in a number of modified gravity theories.

Monday morning / 19

Magnetar Evidence in Central Engines of Peculiar Gamma-Ray Bursts

Author: Binbin Zhang[1]

[1] *Nanjing University*

Corresponding Author: bbzhang@nju.edu.cn

Recent observations of peculiar gamma-ray bursts (GRBs), such as GRB 211211A and GRB 230307A, challenge the traditional view that hyper-accreting black holes power these events. Instead, key signatures—temporal, spectral, and kilonova features—suggest millisecond magnetars as central engines, formed in compact star mergers. This talk highlights recent progress in understanding magnetar-driven GRBs and discusses their implications for GRB progenitors, neutron star physics, and merger energetics.

Tuesday afternoon / 20

Long timescale numerical simulations of large, super-critical accretion discs [online]

Author: Chris Fragile[1]

[1] *College of Charleston*

Corresponding Author: fragilep@cofc.edu

In this talk, I will report on some of the largest (in terms of simulation domain size) and longest (in terms of duration) 3D general relativistic radiation magnetohydrodynamic simulations of super-critical accretion onto black holes. The simulations are all set for a rapidly rotating ($a_* = 0.9$), stellar-mass ($M_{\rm BH} = 6.62 M_\odot$) black hole. The simulations vary in their target mass accretion rates (assumed measured at large radius). The results show that all of the simulations settle close to a net accretion rate of $\dot{m}_{\rm net} = \dot{m}_{\rm in} - \dot{m}_{\rm out} \approx 1$ (over the radii where our simulations have reached equilibrium), where $\dot{m} = \dot{M}/\dot{M}_{\rm Edd}$, despite the fact that the inward mass flux (measured at large radii) $\dot{m}_{\rm in}$ can exceed 1,000 in some cases. This is possible because the outflowing mass flux $\dot{m}_{\rm out}$ adjusts itself to very nearly cancel out $\dot{m}_{\rm in}$, so that at all radii $\dot{M}_{\rm net} \approx \dot{M}_{\rm Edd}$. In other words, these simulated discs obey the Eddington limit. The results are compared with the predictions of the slim disc (advection-dominated) and critical disc (wind/outflow-dominated) models and are found to agree quite well with the critical disc model both qualitatively and quantitatively.

Tuesday afternoon / 21

Acceleration and plunge near a rotating black hole

Author: Vladimir Karas[1]

Co-author: Ondrej Kopacek [2]

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

[2] *Technical University of Liberec*

Corresponding Authors: vladimir.karas@asu.cas.cz, ondrej.kopacek@tul.cz

We explore off-equatorial acceleration of electrically charged matter near a magnetized black hole with the aim of understanding the boundaries between the regions of stable, plunging, and escaping motion. As a generalisation of the Innermost Stable Circular Orbit (ISCO), the concept of the radius of the Innermost Stable Spherical Orbit (ISSO) determines the inner rim of inclined accretion/ejection process. We demonstrate that the region of bound orbits has a complicated structure due to enhanced precession in strong gravity. We also explore the fate of particles launched in the near-horizon region: these may either plunge into the event horizon or accelerate to very high energy towards radial infinity (cf. The Astrophysical Journal, Volume 966, id.226, 2024; https://arxiv.org/abs/2404.04501).

Monday morning / 22

The structure of relativistic jets and their magnetic fields

Author: Asaf Pe'er[1]

[1] *Bar Ilan University*

Corresponding Author: asaf.peer@biu.ac.il

Relativistic jets are ubiquitous on many different systems. From stellar-size objects such as X-ray binaries (XRBs) and gamma-ray bursts (GRBs) to billion times larger such as in active galactic nuclei (AGNs). Similarly, the inferred Lorentz factors of the jets range from mildly relativistic to ultra-relativistic with Gamma ~1000 in some GRBs. Despite decades of research, the structure, geometry and composition of jets is still highly debatable, with contradicting data.
Geoemtry-wise, it is now clear that jets are structured, which gives room to various phenomena, such as photon energy gain by repeated scattering. Contradicting data exists for the magnetic field and composition: in AGNs, the leading mechanism for jet production is Blandford-Znajek, which results in Pointing-dominated outflow. Magnetic field is measured using Faraday-rotation techniques. On the other hand, fitting GRB data indicates matter-dominated jets. I will discuss various possibilities of overcoming these discrepancies, including (i) neutrino contribution; (ii) matter injection via instabilities; and (iii) matter injection during the black hole formation.

Tuesday morning / 23

Magnetic field dynamics in isolated neutron stars: insights from GRMHD simulations

Author: Aurora Capobianco[1]

Co-authors: Sebastiano Bernuzzi [1]; William Cook [1]; Brynmor Haskell [2]

[1] *Friedrich-Schiller-Universität Jena*

[2] *Università degli Studi di Milano*

Corresponding Authors: william.cook@uni-jena.de, sebastiani.bernuzzi@uni-jena.de, aurora.capobianco@uni-jena.de, brynmor.haskell@unimi.it

The internal magnetic field topology and equilibrium configurations of neutron stars are thought to play a fundamental role in determining the nature and strength of astrophysical phenomena. We model the development of the super strong magnetic fields in neutron stars using the General Relativistic MagnetoHydroDynamic (GRMHD) code AthenaK. In this talk, I will present the long-term evolutions of isolated neutron stars with an outer dipole-like field and various initial internal magnetic-field configurations, exploring the growth times of the various instability-driven oscillation modes and turbulence. I will highlight how resolution impacts the magnetic field evolution due to instabilities that arise from small-scale effects and discuss future developments.

Tuesday afternoon / 24

Pseudo-Newtonian Simulations With Reissner–Nordström Naked Singularity

Author: Miljenko Čemeljić[1]

Co-author: Wlodek Kluźniak [2]

[1] *CAMK & SGMK & SU & ASIAA*

[2] *CAMK*

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

We present a new pseudo-Newtonian potential for the gravity around a Reissner–Nordström naked singularity and perform numerical simulations of matter encircling such object. Simulations with our potential reproduce exactly the radial dependence of the Keplerian orbital frequency, with the orbital angular velocity vanishing at the zero gravity radius and showing a maximum at 4/3 of that radius. The accretion stops at a certain distance away from the singularity, where the material is accumulating in a toroidal structure close to the zero-gravity sphere. Such rotating ring could be observed by the methods developed in Event Horizon Telescope collaboration. Our simulations show that some features of naked singularity could be probed in simulations with the pseudo-Newtonian potential, which are less numerically demanding than simulations in general relativity.

Monday afternoon / 25

Exploring the Dynamics of Magnetically Arrested Disks: The Role of Radiative Cooling

Author: Akshay Singh[1]

[1] *Bar-Ilan University*

Corresponding Author: akshaysingh02468@gmail.com

Accretion disks are essential for understanding the dynamics of gas around black holes. The magnetically arrested disk (MAD) state, where the magnetic flux near the event horizon becomes saturated, has garnered significant attention following observations of supermassive black holes in M87 and Sagittarius A*by the Event Horizon Telescope (EHT) collaboration, which suggest that this is the preferred accretion state for such systems. In particular, low-luminosity systems like Sagittarius A* are significantly influenced by radiative cooling processes, which profoundly affect the thermal, magnetic, and dynamical properties of the accretion disk. In this talk, I will describe how radiative cooling impacts the structure and behavior of MADs at sub-Eddington accretion rates. We analytically identify a critical mass accretion rate below which synchrotron radiation becomes a dominant cooling mechanism, altering the disk's thermal equilibrium and the MAD parameter. Using general relativistic magnetohydrodynamic (GRMHD) simulations from our massively parallel code cuHARM, I will explore how these cooling effects influence force balance, magnetic saturation, and jet efficiency for a range of black hole spins and accretion rates.

Monday afternoon / **26**

Do we understand pair cascade in AGN jets?

Author: Mikhail Medvedev[1]

[1] *U. Kansas & MIT*

Corresponding Author: medvedev@ku.edu

Observations of the 3C120 jet indicate that this jet is likely pair-dominated [Zdziarski, et al. 2022]. This result implies strong production of the electron-positron plasma in the system. The currently accepted model of pair production involves an electromagnetic cascade near the base of the jet. Numerically solving the model equations one shows that the cascade indeed forms and can populate the jet with lepton plasma. Yet, it seems the pair plasma production rate is smaller than that following from observations. Here we discuss this problem.

Wednesday morning / **27**

Radiative GRMHD simulations of sub-Eddington accretion: the Puffy disc

Author: Debora Lančová[None]

Corresponding Author: dlancova@camk.edu.pl

A widely accepted picture of an accretion flow in the luminous soft spectral state of X-ray binary systems is a geometrically thin disc structure much like the classic analytic thin disc model of Shakura & Sunyaev. Although the analytic models are troubled by instabilities, they are successfully used to interpret observational data. I will present the results of general relativistic radiative magnetohydrodynamic (GRRMHD) simulations of sub-Eddington optically thick accretion on a stellar-mass black hole with a mildly sub-Eddington luminosity, the so-called Puffy disc. The accretion flow is stabilised by the magnetic field, with a puffed-up optically thick region resembling a warm corona surrounding a denser disc core. However, the distinguished vertical structure of the disk has a significant influence on the observable picture of such a system and affects the central black hole parameters obtained using standard tools to interpret observational data.

Monday afternoon / **28**

Energy flow and radiation luminosity in the simulations of neutron star Ultraluminous X-ray sources

Author: Fatemeh Kayanikhoo[1]

Co-authors: Wlodek Kluźniak [2]; Miljenko Čemeljić [3]

[1] *Silesian University in Opava*

[2] *CAMK*

[3] *CAMK & SU & ASIAA*

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

ULXs are non-nuclear extragalactic sources that emit X-rays at luminosities exceeding $10^{39}\ erg/s$. One of the most accepted models to explain the extraordinary luminosity of ULXs is the super-Eddington accretion onto stellar-mass compact objects. This model with the central object of a neutron star revived interest in 2014, after the discovery of the neutron star-like pulsation period in some ULX emissions (e.g. ULX M82 X–2).

Both numerical simulations and analysis of observational data are necessary to explore the physics responsible for the pulsation and high-rate X-ray emission of these objects. We investigate the energy flow and radiation efficiency of accreting magnetized neutron stars as ULXs through numerical simulations. In this investigation ten GRRMHD simulations are performed with six different magnetic dipole strengths ranging from 10 to 100 GigaGauss, and three accretion rates—100, 300, and 1000 times the Eddington luminosity units.

The key takeaway from this study is that variations in accretion rate and magnetic dipole strength influence the accretion structure and luminosity efficiency of the system which in turn, affects the inferred luminosity, allowing us to categorize the system as either a ULXs or not. The magnetic dipoles in order of 10 GigaGauss and the accretion rates above 300 Eddington luminosity units lead to the development of strong radiatively driven outflows. These outflows enhance geometric beaming, resulting in apparent luminosities that are consistent with those observed in ULXs. We found that in the simulation with the magnetic dipole of 10 GigaGauss, the apparent luminosity is about 120 Eddington units. For the dipole one order of magnitude stronger this value is only 40 Eddington units. Increasing the accretion rate to 1000 Eddington luminosity in the weak magnetic dipole simulation results in the apparent luminosity of about 250 Eddington units.

Monday morning / 29

cuHARM: general relativistic radiation magneto-hydrodynamics in the era of exascale computing

Authors: Asaf Pe'er[1]; Damien Bégué[2]

[1] *Bar Ilan University*

[2] *Bar-Ilan University*

Corresponding Authors: asaf.peer@biu.ac.il, cayley38@gmail.com

I will present cuHARM, a general relativistic radiation magnetohydrodynamic solver optimized to exploit exascale computing facililties. After describing the core numerical strategy for multi-node and multi-GPU setups, I will detail how radiation and its feedback on the dynamics are modeled. In cuHARM, the specific intensity is discretized in space and momentum, and is evolved through the solution of the radiative transfer equation via the discrete ordinate method. This approach does not require the use of a closure relation and allows to resolve in details the anisotropy of the specific intensity. I will then present the performance of the numerical approach on known radiative test problems as well as our first results of radiative accretion at 0.1 Eddington luminosity.

Wednesday morning / 31

GRMHD simulations of accretion disks: QPOs, truncated disks and QPOs from truncated disks

Author: Gibwa Musoke[1]

[1] *Canadian Institute for Theoretical Astrophysics*

Corresponding Author: gmusoke@cita.utoronto.ca

Black hole X-ray binaries (BHXRBs) and Active Galactic Nuclei (AGN) transition through a series of accretion states in a well-defined order. The accretion states, each associated with different luminosities, spectral and variability characteristics, quasi periodic oscillations (QPOs) and outflow properties, are thought to be triggered by physical changes in the accretion disk around the central black hole.The mechanisms behind state transitions, the geometry of transitional disks and the physical mechanisms driving the emission characteristics we observe remain highly debated.

General relativistic magneto-hydrodynamic simulations (GRMHD) are increasingly providing crucial insights into the accretion process, the launch of outflows and the physical processes driving state transitions in BHXRBs and AGN. Using GRMHD simulations conducted with the H-AMR code I: 1) Discuss how high and low-frequency QPOs can be produced by a highly tilted, geometrically thin accretion disk. 2) Present the first GRMHD simulation showing the self-consistent formation of a truncated accretion disk–a proposed disk model for the hard intermediate accretion state, in which the accretion flow is thick and hot close to the black hole, while the outer regions of the flow are thin and cool. 3) Describe how QPOs can be generated at the truncation radius (the radius at which the disk transitions from thick to thin) in a truncated accretion disk.

Tuesday afternoon / 32

Simulating a planet inside highly relativistic pulsar wind

Author: Tanja Kaister[1]

Co-author: Miljenko Čemeljić [2]

[1] *CAMK*

[2] *CAMK & SU & ASIAA*

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

We investigated a novel pulsar planet detection method based on radio emissions produced by the interaction of a terrestrial planet with the pulsar wind.
Using the PLUTO code, we simulate relativistic magnetohydrodynamics of an Earth-sized planet ensconced in a highly relativistic pulsar wind. We achieved a Lorentz factor of approximately 6 or a pulsar wind speed of approximately 98.5\% of the speed of light in our simulation.
We examine the effects of changes in pulsar wind densities and external magnetic field strengths on the radio emission characteristics and compare the results with previous studies at lower velocity. The resulting emissions show characteristics similar to those of Alfven wing structures, in which wing-like disturbances in the flow are produced by the interaction of a conducting barrier with a magnetized plasma. Our findings suggest that radio emissions from a planet the size of Earth can have intensities that are within the current radio telescopes' sensitivity limits; thus this offers a new opportunity to search for planets around pulsars using existing data and a base for new observation proposals. Furthermore, the anticipated spectrum properties provide a diagnostic for differentiating terrestrial pulsar planets from other astrophysical radio emitters.

:CFT Special seminar / 33

Comparison of solutions with different pseudo-Newtonian potentials in numerical simulations of accretion disk around compact objects

Author: Maria Koper[1]

Co-authors: Miljenko Čemeljić [2]; Włodzimierz Kluźniak [3]

[1] *University of Warsaw*

[2] *SGMK, CAMK, SU & ASIAA*

[3] *CAMK*

Corresponding Author: mz.koper@student.uw.edu.pl

I present hydrodynamic simulations of a thin accretion disk around compact objects using three different pseudo-Newtonian potentials: the Paczyński–Wiita and Kluźniak–Lee for a Schwarzschild black hole, and the newly devised potential for a Reissner–Nordström (RN) naked singularity. I study the differences between the properties of disks surrounding Schwarzschild black holes in two related pseudo-Newtonian potentials and compare the results with those for the RN naked singularity. The Paczyński–Wiita solution accurately reproduces the location of stable and bound orbits, as well as the form of the Keplerian angular momentum, while the Kluźniak–Lee potential reproduces the ratio of the orbital and epicyclic frequencies. I analyze the radial dependence of angular momentum, angular velocity, and epicyclic frequency, comparing these properties with those predicted by each pseudo-Newtonian potential. For the RN naked singularity, I consider different values of the charge-to-mass ratio, which affects the localization of orbits for test particles. Accretion around the naked singularity stops at the zero-gravity sphere, where angular velocity vanishes. Due to the effective potential, gravity inside this sphere is repulsive, causing the disk to assume a toroidal structure that encompasses the singularity, which is consistent with the analytic solution in general relativity. In the case of black holes, matter approaching the event horizon undergoes narrowing, with the disk either remaining thin for the rest of its length or thickening, depending on the chosen pseudo-potential. Unlike black holes, naked singularities in the simulations are found to be sources of outflows which, combined with the distinct geometry of the sources, may provide a valuable tool for distinguishing these compact objects in observations with facilities such as the Event Horizon Telescope.

Tuesday morning / 34

Turbulence and magnetic configurations in neutron star interiors

Authors: Brynmor Haskell[1]; RAJ KISHOR JOSHI[2]; William Cook[3]

[1] *CAMK PAN*

[2] *Nicolaus Copernicus Astronomical Center*

[3] *Friedrich-Schiller-Universität Jena*

Corresponding Authors: bdlhaskell@gmail.com, william.cook@uni-jena.de, rjoshi@camk.edu.pl

I will discuss the issues related with calculating the magnetic field structure in the interior of neutron stars, and how numerical simulations can be used to asses the stability and evolution of such configurations.
In particular I will focus on instabilities and on the development of turbulence. I will show new results in which the turbulence is resolved, and discuss it's impact on astrophysical observables.

Tuesday morning / 35

MHD Simulations of Type I Bursts

Author: Yuri Cavecchi[1]

[1] *Universitat Politecnica de Catalunya*

Corresponding Author: yuri.cavecchi@upc.edu

When Neutron Stars are in orbit with a companion star, they can capture the outer layers of the latter. This new matter can burn unstably on the surface of the star and explode in bright X-ray flashes called the Type I Bursts.

In this talk I will show results of MHD modelling of the flame during the Type I Bursts and discuss its link to observations and to the properties of the neutron stars such as their magnetic fields or their interior physics.

Tuesday afternoon / **36**

Binary black holes in magnetized AGN disks

Author: Raj Kishor Joshi[1]

[1] *Nicolaus Copernicus Astronomical Center*

Corresponding Author: rjoshi@camk.edu.pl

I will present magnetohydrodynamic (MHD) simulations of a binary black hole (BBH) system embedded within a magnetized active galactic nucleus (AGN) disk, aiming to explore the accretion dynamics and the formation of outflows. Unlike traditional models that assume a circumbinary accretion disk around the binary, our approach allows the interaction between the binary system and the surrounding disk to govern the accretion flow. The evolution of BBHs in AGN disks depends on the intrinsic parameters of the binary, such as mass ratio, separation, orbital frequency, and the properties of the surrounding gas. Additionally, magnetic fields in AGN disks have been recognized as an important factor influencing the accretion process. Our MHD simulations do not assume a pre-existing circumbinary disk and instead focus on the self-consistent development of accretion flows driven by the interaction between the BBH and the disk. The results provide new insights into the complex dynamics of embedded BBH systems and highlight the critical role of magnetic fields in shaping accretion behavior, including the potential for episodic accretion events and outflow formation in the pre-merger phase, which could create favorable conditions for radiation to escape from optically thick AGN disks.

Monday afternoon / **37**

Machine Learning Enhanced Photometric Analysis of the Extremely Bright GRB 210822A

Author: Camila Angulo-Valdez[1]

Co-authors: Rosa L Becerra [2]; Margarita Pereyra [1]; Keneth Garcia-Cifuentes [3]; Felipe Vargas [3]; Alan M. Watson [1]; Fabio De Colle [3]

[1] *Instituto de Astronomía, Universidad Nacional Autónoma de México*

[2] *Department of Physics, University of Rome - Tor Vergata*

[3] *Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México*

Corresponding Authors: fabio@nucleares.unam.mx, camiangulo@astro.unam.mx, alan@astro.unam.mx, mpereyra@astro.unam.mx, stivengarcia7113@gmail.com, rosa.becerra@roma2.infn.it

We apply machine learning techniques to model the multi-wavelength emission of the extremely bright GRB 210822A using the AFTERGLOWPY library. This approach allows us to estimate the

observer angle θ_{obs}, the initial energy E_0, the electron index p, the thermal energy fractions in electrons (ϵ_e) and in the magnetic field (ϵ_B), the efficiency χ, and the density of the surrounding medium n_0. To achieve this, we train a neural network on 30,000 synthetic AFTERGLOWPY light curves and apply it to this event.

We also analyse the temporal and spectral evolution of the optical and X-ray emissions. Our results show that a reverse shock component dominates the early-time emission, while a jet break is observed at later times. This break allows us to constrain the jet opening angle θ_j to a value consistent with that obtained through the machine learning code.

Monday morning / 38

Identification of Extended Emission Gamma-Ray Burst Candidates Using Machine

Authors: Fabio De Colle[1]; Keneth Stiven Garcia Cifuentes[1]; Rosa Leticia Becerra Godinez[2]

[1] *Instituto de Ciencias Nucleares, UNAM*

[2] *Università degli Studi di Roma, Tor Vergata*

Corresponding Authors: keneth.garcia@correo.nucleares.unam.mx, rosa.becerra@roma2.infn.it, fabio@nucleares.unam.mc

In this work, I will presentthe t-distributed stochastic neighbour embedding (t-SNE), a machine-learning technique, to classify GRBs. We present the results for GRBs observed until 2022 July by the Swift/ BAT (Burst Alert Telescope)instrument in all its energy bands. We show the effects of varying the learning rate and perplexity parameters, as well as the benefit of preprocessing the data by a nonparametric noise-reduction technique. Consistently with previous works, we show that the t-SNE method separates GRBs into two subgroups. We also show that EE GRBs reported by various authors under different criteria tend to cluster in a few regions of our t-SNE maps and identify seven new EE GRB candidates by using the gamma-ray data provided by the automatic pipeline of Swift/BAT and the proximity with previously identified EE GRBs.

Tuesday morning / 39

Numerical Simulations of Supercritical Accretion Flows Around a Compact Object

Author: Yuta Asahina[1]

Co-authors: Akihiro Inoue [2]; Hiroyuki Takahashi [3]; Ken Ohsuga [4]

[1] *Tohoku University*

[2] *University of Tokyo*

[3] *Komazawa University*

[4] *University of Tsukuba*

Corresponding Authors: asahina557@gmail.com, ohsuga@ccs.tsukuba.ac.jp, takhshhr@komazawa-u.ac.jp, inoue-a@g.ecc.u-tokyo.ac.jp

Rotating plasma forms an accretion disk around compact objects such as black holes and neutron stars. The gravitational energy released during accretion is converted into the kinetic energy, internal energy, and radiation energy. A portion of the converted energy is ejected into interstellar space via outflows and radiation. However, the detailed structure of the accretion disk and the mechanisms driving these outflows are not yet fully understood. In highly luminous systems, such as ultra-luminous X-ray sources, the interaction between the radiation and magnetofluids cannot

be ignored and must be properly treated. Therefore, general relativistic radiation magnetohydrodynamics (GR-RMHD) simulations taking into account the effect of the radiation are needed. In this talk, I will present recent numerical studies for GR-RMHD simulations of super-Eddington accretion flows and discuss implications for the accretion dynamics.

Tuesday afternoon / 40

First Results from Spritz: A GRMHD Code for Binary Neutron Star Mergers with Microphysical Equation of State

Author: Fatemeh Hossein Nouri[1]

[1] *INFN, University of Milano-Bicocca*

Corresponding Author: fatemeh.hosseinnouri@mib.infn.it

We present first results from Spritz, a general-relativistic magnetohydrodynamics (GRMHD) code developed for high-precision simulations of binary neutron star (BNS) mergers using nuclear equations of state. Spritz is designed with a focus on robustness and accuracy, incorporating high-order shock-capturing schemes and support for tabulated equations of state, allowing for the inclusion of neutrino radiation. The code is built on the Einstein Toolkit infrastructure, which provides adaptive mesh refinement (AMR) and optimized parallel performance for large-scale simulations.

In this study, we assess the accuracy of Spritz in evolving both magnetized and non-magnetized equal-mass BNS systems with realistic microphysical input. The simulations reliably capture the inspiral, merger, and early post-merger phases, producing consistent gravitational waveforms and detailed remnant structures.

These initial results demonstrate the code's capability as a foundation for more comprehensive studies. We conclude by outlining planned investigations, including ejecta characterization and the conditions for the formation of relativistic jets—key to understanding high-energy transients such as short gamma-ray bursts and kilonovae.

Monday afternoon / 42

3D geometry and magnetic connections of erupting black hole jet

Author: Mateusz Kapusta[1]

Co-authors: Bart Ripperda [2]; Krzysztof Nalewajko [3]; Sasha Philippov [4]

[1] *Astronomical Observatory, University of Warsaw*

[2] *CITA, U. Toronto*

[3] *Nicolaus Copernicus Astronomical Center, PAS, Warsaw, Poland*

[4] *U. Maryland*

Corresponding Authors: mr.kapusta@student.uw.edu.pl, knalew@camk.edu.pl

In recent years, the Magnetically Arrested Disc (MAD) model of accretion flows onto spinning black holes has gained significant attention due to its consistency with several observations, including those of Sgr A$*$ and M87$*$. Such discs support powerful relativistic jets and episodic magnetic flux eruptions powering high-energy flares, which were also found to impact the structure of the inner accretion flow. In this work, we investigate the influence of the eruptions on the structure of the relativistic jets and the accretion flow with the help of extreme-resolution (effectively $5376 \times 2304 \times 2304$ cells) general relativistic magneto-hydro-dynamical simulations first presented in Ripperda et al

(2022). We investigate the 3D structure of jets, including the axisymmetric component as well as departures from axisymmetry, to distances of ~ 10^3 gravitational radii at different stages in the cycle of magnetic flux accumulation and eruptions. The impact of external magnetic flux tubes on the jet structure is particularly strong after a major eruption weakens the jets. We trace extensive samples of magnetic field lines to examine the magnetic connectivity between the jets, the wind, the accretion flow and the hotspots ejected from the jet during eruptions. We describe how the ejected magnetic flux tubes connect equatorial hotspots with the jet spine/sheath while crossing the wind region at various post-eruption stages.

Tuesday afternoon / 43

Decoding M87's emission: A New Physically Consistent Model for Its Active Nucleus

Author: Sabrina Pizzicato[1]

[1] *University of Lodz*

Corresponding Author: sabpizzicato@gmail.com

We present preliminary results of our attempt to build a physically consistent model for the active nucleus of the galaxy M87, based on the GRMHD simulations. Our model simultaneously reproduces the broad-band spectrum and intensity maps, offering a unified explanation of these observations. In our solution, most of the radiation observed at frequencies above 100 GHz originates from the inner accretion flow rather than the jet. Our results highlight the need to include the role of electron energy balance in modeling active galactic nuclei (AGN), demonstrating that commonly used artificial prescriptions for electron temperature tend to overestimate it, leading to discrepancies with observed properties. This work underscores the necessity of physically motivated electron thermodynamics for accurately interpreting high-resolution VLBI images of M87 and other AGN.

Tuesday afternoon / 44

Radiative model of MADs and its application to M87*

Author: Andrzej Niedzwiecki[None]

Corresponding Author: andrzej.m.niedzwiecki@gmail.com

We study spectra produced by weakly accreting black hole systems using the GRMHD simulations. We highlight the role of large temperature fluctuations, which characterise the GRMHD solutions, in shaping the broadband spectrum and find that this effect can explain the SED observed in the active nucleus of galaxy M87. We apply our model to VLBI images of this active nucleus, but find that the constraints on the physical model are relatively weak at their current angular resolution. We also discuss the applicability of the popular R-beta prescription for the electron temperature to the interpretation of the observed spectra and images.

Monday afternoon / 45

Numerical simulations of GRB jets from the BH horizon to post-breakout in collapsing stars

Author: Gerardo Urrutia[1]

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

Corresponding Author: gurrutia@cft.edu.pl

GRBs from collapsars have been studied by imposing jets at intermediate scales beyond the iron core region while exploring a wide range of parameters, such as luminosity and central engine duration. However, these conditions should be validated by studying jets launched directly from the central engine to show a global picture of the jet propagation inside and outside of the progenitor star. In this talk, I will present two dimensional GRMHD simulations of GRB jets launched from a black hole and followed through to breakout from the collapsing star. From our simulations, I will discuss the implications of the inner progenitor structure and magnetization on the properties of the jet emission (launching, duration, structure, and the variability).

Monday afternoon / **46**

Impact of Self-Gravity on Jet Properties in Collapsar Models

Author: Piotr Płonka[1]

[1] *University of Warsaw*

Corresponding Author: p.plonka@student.uw.edu.pl

This study focuses on the analysis of relativistic jets in collapsars with a self-gravitating stellar envelope. In our simulations the initial mass of the black hole is three solar masses, while the stellar envelope mass is twenty-five solar masses. Therefore, self-gravity cannot be neglected in the analysis. We compare two models—with and without self-gravity—under identical initial conditions, with a 5% perturbation to the internal energy of the envelope, which allows us to investigate the influence of small-scale variations on jet dynamics and stability. Our main goal is to determine the effect of the self-gravitating envelope on jet properties, such as the Lorentz factor, opening angle, velocity profile, emitted energy during the process, and jet collimation. Additionally, we study the dynamical evolution of the black hole's spin and mass during jet emission to highlight the impact of self-gravity on these parameters.

Tuesday afternoon / **47**

Determining the role of irradiation in radiation pressure instabilities.

Author: Federico Vincentelli[1]

[1] *INAF IAPS*

Corresponding Author: vincentelli.astro@gmail.com

It has been known since the 70's that accretion disks are unstable above an accretion rate of ~10% Eddington. Yet, despite the several accreting systems known, only a handful of stellar mass black holes have been showing clear signs of accretion disk instabilities. Through an unprecedented multiwavelength campaign of a highly accreting neutron star, it has been recently shown that the whole phenomenology of these systems can be explained in terms of radiation pressure instability. This opens a new avenue to solve this long standing problem by analysing the contribution of irradiation on the disk. Given this, I will present the first results on a new version of GLADIS which includes radiation from a central object. Preliminary results show that this component changes the profile of the heartbeats oscillations. Systematic analysis of this feature will allow in the future to understand the onset and the periodicity of this phenomenon for different irradiation strength.

:CFT Special seminar / 48

Numerical studies of relativistic jets from black holes

Author: Krzysztof Nalewajko[1]

[1] *Nicolaus Copernicus Astronomical Center, PAS, Warsaw, Poland*

Corresponding Author: knalew@camk.edu.pl

Relativistic jets are powerful collimated outflows from accreting compact objects, especially spinning black holes. Jets, as well as their associated mechanisms of energy dissipation and particle acceleration, can be investigated by global or local numerical simulations using methods like general-relativistic magneto-hydro-dynamics (GRMHD), particle-in-cell (PIC), etc. This presentation highlights selected results from 3 projects related to relativistic jets.

Monday afternoon / 49

Simulations of hungry yet picky black holes [online]

Author: Sasha Tchekhovskoy[1]

[1] *Northwestern University*

Corresponding Author: atchekho@northwestern.edu

In this talk, I will overview the results of recent simulations of black holes that are hungry, yet picky: they end up ejecting most of the gas they have access to. I will discuss the factors that affect their picky-ness and make the connection to the production of relativistic collimated outflows, or jets.

Tuesday afternoon / 50

Understanding Supernova Engines and the Properties of Compact Remnants [online]

Author: Chris Fryer[1]

[1] *Los Alamos National Laboratory*

Corresponding Author: fryer@lanl.gov

The energy released in the collapse of the core of a massive star are believed to produce a wide range of astrophysical transients including core-collapse (type Ib, Ic, II) supernovae and long duration gamma-ray bursts. A number of engines have been proposed to extract the energy released in the collapse and power an energetic explosion. All of the proposed engines are likely to occur in nature. But differentiating which engines produce which transients remains a point of intense discussion. A broad range of observations have focused on distinguishing these different engines. One of the most promising constraints has been observations of the properties of compact remnants: masses, spins, proper motions (a.k.a. kicks). Here I review the predictions of these compact remnant properties and show how observations of these properties have begun to constrain the nature of core-collapse engines.

Wednesday morning / 51

Beyond the Kerr Black Hole-Torus paradigm

Author: Hector Raul Olivares Sánchez[1]

[1] *Universidade de Aveiro*

Corresponding Author: h.sanchez@ua.pt

Developments in observing technology have produced the first event-horizon-scale images of accreting supermassive black holes. The interpretation of such observations relies on sizable libraries of synthetic data produced from general-relativistic magnetohydrodynamic (GRMHD) simulations. This approach has provided considerable insight into these systems, but also suffers from some limitations. In particular, most of the libraries consist of the same physical scenario: a Kerr black hole surrounded by a rotation-supported torus seeded with poloidal magnetic fields. Two limitations of this model are its lack of connection with the parsec-scale accretion flow, and the lack of models considering spacetime geometries different from Kerr black holes. In this talk, we will explore a selection of the literature on alternative models, both from the side of different spacetime geometries and from that of different accretion models. In particular, we will focus on how insights from stellar-wind-fed accretion simulations have been incorporated in GRMHD simulations, and on the importance of understanding the accretion process in the search for signatures of new fundamental physics.

Tuesday morning / 52

Radiation hydrodynamical simulations of super-Eddington mass-transfer in close BH binaries

Author: Daisuke Toyouchi[1]

[1] *Osaka University*

Corresponding Author: d.toyouchi@gmail.com

Radiation-driven outflows play a crucial role in extracting mass and angular momentum from binary systems undergoing rapid mass transfer at super-Eddington rates. We study this process by conducting three-dimensional radiation hydrodynamical simulations of mass-transferring BH binary systems. Our simulations show that super-Eddignton mass transfer leads to a significant mass loss from the binary system due to radiation-driven outflows. The mass and angular momentum loss rates are high enough to make the mass transfer unstable, indicating a new pathway for driving the common envelope evolution. Thus, our simulation results provide an important implication for the formation of close binary BHs that merge within the Hubble time.

:CFT Special seminar / 53

Probing Radiation Pressure Instabilities in Neutron star LMXBs

Authors: Agnieszka Janiuk[None]; Bozena Czerny[1]; Pulkit Ojha[2]

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

[2] *Centrum Fizyki Teoretycznej PAN*

Corresponding Authors: agnes@cft.edu.pl, pojha@cft.edu.pl, bcz@cft.edu.pl

X-ray binaries hosting compact objects exhibit various variabilities in their X-ray spectra, often attributed to thermoviscous instabilities within their accretion disks. In particular, short-term variabilities , believed to arise from radiation pressure instabilities (RPIs) from the inner regions of the disk, have been well studied in black hole (BH) X-ray binaries. Recent observations suggest that similar variability patterns are also present in neutron star (NS) X-ray sources. Vincentelli et al. (2023) reported such behavior in the NS system Swift J1858.6−0814, suggesting a possible shared instability mechanism between BH and NS systems.

Our work aims to investigate these short-term variabilities by modeling the accretion disks of neutron star low-mass X-ray binaries (NS LMXBs). In order to better understand the structure of the flow in the case of the neutron star and to properly formulate the boundary conditions for time evolution we attempt an analytical approach, with averaged equations to obtain a tentative solution for the boundary layer radius and its other properties in equilibrium state. This poster presents the key aspects of modelling the time-independent structure of the accretion disk and a few preliminary results.

In future work, we plan to employ the Global Accretion Disk Instability Simulator (GLADIS) code, originally developed by Janiuk et al. (2002) to simulate RPIs in BH systems. To adapt the code for neutron star systems, we will incorporate the effects of the NS boundary layer and irradiation feedback from the star onto the disk. This involves modifying the heat transfer equations and introducing radial transport of momentum to capture the sub-Keplerian structure of the disk near the NS surface.

:CFT Special seminar / 54

Polarisation due to returning thermal disk radiation in the soft state of black-hole binaries

Author: Aishee Chakraborty[1]

Co-author: Andrzej Niedzwiecki

[1] *University of Lodz*

Corresponding Authors: andrzej.m.niedzwiecki@gmail.com, aisheephd@gmail.com

Reflection of thermal disk emission returning to the disk has recently been claimed to be important in the soft states of black hole binaries. In particular, Steiner et al. (2024) proposed that it could explain the X-ray polarisation measured by IXPE in the soft state of Cyg X-1. This would be an important argument for rapid rotation of black holes in HMXBs, since the effect is only important for the spin values close to the extreme. We have extended the relativistic reflection model reflkerr to include this effect and we find that our results are in full agreement with those of Schnittman & Krolik (2009), who first discussed this effect. However, we find that it is very unlikely to give an observable signal in real accretion systems, since even for extreme spin values it would be completely outweighed by the radiation of the X-ray corona, whose presence is often required by hard X-ray data. For example, for the black hole mass and accretion rate relevant to Cyg X-1, and in the absence of any coronal emission, the polarisation signal due to the returning thermal radiation would indeed be similar to that measured by IXPE. However, the presence of the coronal component measured by NuSTAR reduces the degree of polarisation associated with the returning thermal radiation to less than 1%, making this effect unimportant.

Special Seminar / 55

Today's Discoveries, Tomorrow's Frontiers: Multi-Messenger Astrophysics

Author: Ore Gottlieb[1]

[1] *CCA, Flatiron Institute*

Corresponding Author: oregottlieb@gmail.com

Multi-messenger events involving gravitational waves (GWs) offer an unparalleled view into some of astrophysics' most profound mysteries. To date, detections have been limited to mergers of neutron stars and black holes - the powerhouses behind the universe's brightest emission: short-duration gamma-ray bursts (GRBs). However, recent observations of long GRBs accompanied by kilonovae have revealed an unexpected new class of long-duration GRBs originating from binary mergers, challenging our understand of the engines driving GRBs - are they neutron stars or black holes?

In this talk, I will present a unification model that elucidates the engines of short and long GRBs, linking these explosive events to the underlying binary populations. This framework allows us to directly associate the distinctive signatures of mergers with their astrophysical origins. I will conclude the talk by exploring what future multi-messenger detections might uncover - particularly the possibility of detecting the first GW signals from non-merger events. I will demonstrate how accretion disks in rapidly rotating collapsing stars can generate coherent and vigorous GWs, and, when coupled with their supernova electromagnetic signatures, these sources could be prime candidates for the inaugural non-inspiral multi-messenger detection by LIGO.

Monday afternoon / 56

Horizon-scale simulations of galaxy-fueled, strongly magnetized quasars

Author: Nick Kaaz[1]

[1] *Northwestern University*

Corresponding Author: nicholaskaaz@gmail.com

"Classical" accretion disks are geometrically thin, radiatively efficient and mechanized by turbulent viscosity. Yet, many observational and theoretical issues challenge this paradigm. Realistic quasar disks may be fed from cold, highly magnetized gas complexes, which can result in magnetically dominated disks that accrete extremely quickly. I will present horizon-scale simulations of magnetically dominated disks that were self-consistently formed in a galaxy. I will show how the magnetic field evolves in surprising ways as the gas reaches the BH. I will also show how "magnetic flux inversions" naturally emerge within these systems. Such events may power some Changing-look AGN and have analogues in neutron star mergers or tidal disruption events.

Special Seminar / 57

Cosmic Engines: How Black Holes Power the Brightest Objects in the Universe

Author: Omer Bromberg[1]

[1] *Tel Aviv University*

Corresponding Author: omerbr@tauex.tau.ac.il

Black-holes are like the genie of the lamp, as they can store vast amounts of energy within an extremely compact region. Under the right conditions, this energy can be harnessed to power some of the most luminous and energetic phenomena in the universe, like quasars and gamma-ray bursts.

Current theoretical understanding suggests that the energy release is facilitated by the black-hole's rotation and its interaction with magnetic fields supplied by accreted matter. Yet, how the black-hole magnetosphere responds to the energy extraction and by what processes this energy is ultimately converted into the observable emission is still debated. In this talk, I will discuss the necessary conditions near the event horizon that can sustain a stable energy extraction. I will trace the path of the outflowing energy that gives rise to relativistic jets and examine the mechanisms responsible for converting the energy into the observed light. These processes may offer insights into recent observations of core emission from black hole-powered systems.