

GNC 2024

# Galactic Nuclei in the cosmological context

## Meeting Booklet

Szczecin • June 3-6, 2024



**GNC 2024**  
Galactic nuclei in the cosmological context

June 3rd-6th, 2024 - Szczecin, Poland

MUNI  
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# Foreword – Welcome to Szczecin, the *Floating garden!*

*Cześć! Hello! Ahoj!*

I would like to greet you shortly before and then at the *Galactic nuclei in the cosmological context (GNC 2024)* meeting (in person and online), which is taking place in Szczecin, Poland. The idea to organize workshop in Poland arose at the previous *Cologne-Prague-Brno* workshop in 2022 (<https://cpb2022.physics.muni.cz/>), which took place in Brno in Czechia. Many people that share interests in galactic nuclei, both active and quiescent, liked the Brno meeting, mainly because of its atmosphere that created a lot of input for discussions among both experienced and younger participants. I hope we can recreate such an atmosphere in Szczecin as well.

Another motivation for the meeting at this time is our common research grant between National Science Center of Poland and Czech Science Foundation led by Bożena Czerny and me. Currently, the grant is in the middle of its duration and it is a good time to look back at what we have done and what we still should do in the near future. The main topic “Weather effects in using disk continuum time delays in active galactic nuclei to measure the expansion rate of the Universe” is directly related to the rationale of the GNC 2024 meeting and I hope at least one or two research ideas can be initiated at this meeting.

The decision to organize the meeting in Szczecin came after my previous interactions with the active members of the Doctoral School of the University of Szczecin, Michal Rozenberg, Paulina Malkowska, and others. They have been very helpful with all the practical issues related to the venue and without them, it would not be possible to organize such an event. I also appreciate the support for the meeting from the local astrophysicists, especially Prof. Ewa Szuszkiewicz, Prof. Tomasz Denkwicz, and Prof. Vincenzo Salzano. On a personal level, I met Michal Rozenberg as a capable organizer at the Slovak Cultural Institute in the historical center of Warsaw. I immediately recognized that we share common interests in supporting scientific outreach, both among professionals and towards the public, and with his help, I performed a talk on “Astrophysical landmarks in Slovakia” (with my bad polish!), probably the first, hopefully not the last talk on a scientific topic presented at this institute.

Szczecin is a beautiful city, the capital of the Western Pomerania region, at the Oder river and



close to the Baltic Sea. With its population of nearly 400 000 people, developed industry, infrastructure, and the educational sector, it also has big prospects for the future development. It is also has an international flavour that goes back to its membership in the Hanseatic League in the 12th-15th centuries. Szczecin also symbolically went down in modern history as the north-western corner of the “Iron Curtain”. Directly mentioned in the “Sinews of Peace” speech by Sir Winston Churchill at the Westminster College in Fulton, Missouri, on March 5, 1946 – “From Stettin in the Baltic to Trieste in the Adriatic an “iron curtain” has descended across the continent,” – Szczecin as well as other cities and towns in the central and the eastern Europe soon started to directly feel the consequences of the obstacles against their development imposed by the communist regime. After the fall of communism, the city has quickly recovered and with its nickname “Floating garden”, it has an ambition to play a key role in the ecologically clean development of the educational society.

Based on the program and the planned contributions (please visit <https://gnc2024.physics.muni.cz/>), I have no doubts we will learn a lot about several new results concerning the evolution of galactic nuclei and their prospects for the application in cosmological studies. We will do our best to prepare a useful legacy of the GNC 2024 meeting in the form of collected presentations that will remain available at the website and will be linked to the collection available at the NASA ADS. We also anticipate a preparation of a concise report that will be offered to an international journal, potentially also Nature Astronomy, as we did quite successfully for the CPB 2022 meeting (<https://www.nature.com/articles/s41550-022-01785-x>).

I wish everyone an enriching and scientifically productive meeting full of discussions. Furthermore, hopefully you will be able to meet new fellow scientists and experience “floating” vibes of Szczecin and its surroundings.

Michal Zajaček  
on behalf of the GNC2024 LOC & SOC Committees



Figure 1: An aerial view of Szczecin towards the Dabie Lake.



# Chapter 1

## Meeting program

### Monday (June 3rd)

- 14:00-15:15 **Registration at the Doctoral School, University of Szczecin (Adama Mickiewicza 16)**
- 15:30-16:00 **Michal Zajaček, Bożena Czerny, Ewa Szuszkiewicz, Vladimír Karas, [Welcome notes](#)**
- 16:00-16:30 **Michal Zajaček, [Scope of the GNC24 meeting: Galactic nuclei in the cosmological context](#)**
- 16:30-17:00 **Ewa Szuszkiewicz, [From small inhomogeneities of cosmic microwave background to galaxies, stars and planets](#)**
- 17:00-17:30 **Coffee/Tea break**
- History & Architecture session (Chair: Petr Kurfürst)**
- 17:30-18:30 **Michal Rozenberg, [History and Architecture of Szczecin](#)**
- 19:00- **[Welcome Drink & Dinner](#) (*Nowy Browar Szczecin*)**

### Tuesday (June 4th)

**AGN session 1 (Chair: Agnieszka Janiuk)**

- 9:00-9:30 **Bożena Czerny, [Prospects for using AGN from the LSST data to cosmology](#)**
- 9:30-10:00 **Silke Britzen, [Jet precession & Supermassive Binary Black Holes](#)**
- 10:00-10:30 **Piotr Źycki, [Quasi-periodic variability of XRB and AGN - Lense-Thirring precession model](#)**
- 10:30-11:00 **Coffee/Tea break**
- 11:00-11:30 **Francisco Pozo Nunez, [Measuring Quasar Accretion Disc Sizes with the LSST](#)**
- 11:30-12:00 **Catalina Sobrino Figaredo, [Exploring AGN Variability and Cosmological Implications: Photometric Reverberation Mapping of H-alpha emission line in Nearby Seyfert Galaxies](#)**

## Chapter 1 Meeting program

12:00-14:00 **Lunch break** (*Restaurant Artisan*)

**Nuclear Star Clusters session** (Chair: Bozena Czerny)

14:00-14:30 **Petra Suková**, Will UFOs show us SMRIs?

14:30-15:00 **Vladimír Karas**, Modelling the coexistence of a nuclear cluster and a SMBH surrounded by a massive torus

15:00-15:30 **Petr Kurfürst**, Red giant stars' deficiency near the Galactic center as a consequence of the enhanced galactic jet activity in the past

15:30-16:00 **Coffee/Tea break**

**Galactic nuclei evolution & AGN feedback session** (Chair: Francisco Pozo Nunez)

16:00-16:30 **Orsolya Kovács (online)**, High-redshift AGNs & galaxies behind the lensing cluster Abell 2744

16:30-17:00 **Norbert Werner (online)**, Observations of AGN induced dynamics of hot galactic and cluster atmospheres

17:00-17:30 **Saboura Zamani**, Gravitational lensing from clusters of galaxies to test Disformal Couplings Theories

17:30-18:00 **Coffee/Tea break**

**Space weather & Astrobiology session** (Chair: Michal Zajaček)

18:00-18:30 **Michaela Brchnelová**, Space weather modelling at KU Leuven: model chains, limitations and user needs

18:30-19:30 **Franco Ferrari**, Human space travel: an astrobiologist's point of view (popular talk)

19:30- **Free evening program in Szczecin, individual discussions**

## Wednesday (June 5th)

**Sightseeing day: Visit of Świnoujście/Swinemünde**

Bus pick-up at 9 am in Szczecin (to be announced), arrival to Szczecin by 8 pm. Program description: A short tour in Świnoujście with a free program at the Baltic Sea afterwards.

## Thursday (June 6th)

**Low-luminosity galactic nuclei session** (Chair: Petra Suková)

9:00-9:30 **Agnieszka Janiuk**, Broad band spectral modeling of M87 nucleus

9:30-10:00 **Maria Melamed**, Candidate Young Stellar Objects in the S-cluster

## Chapter 1 Meeting program

10:00-10:30 **Myank Singhal**, Evolution of Disk-like Structures in the Galactic Centre

10:30-11:00 **Coffee/Tea break**

**Galactic nuclei/AGN feedback session 1 (Chair: Petra Suková)**

11:00-11:30 **Martin Mondek**, Statistics of Quasi-periodic Eruptions

11:30-12:00 **Tomáš Plšek**, Studying radio-mechanical AGN feedback with X-ray cavities

12:00-14:00 **Lunch break** (*Restaurant Artisan*)

**Galactic nuclei/AGN feedback session 2 (Chair: Catalina Sobrino Figaredo)**

14:00-14:30 **Klaudia Kowalczyk**, Differencing between quiescent and flaring states of blazars using threshold autoregressive models

14:30-15:00 **Alberto Floris**, Chemical abundances along the Quasar Main Sequence

15:00-15:30 **Coffee/Tea break**

15:30-15:45 **Michal Zajaček**, Meeting summary, closing remarks, and what's next

16:30- **Visit of Morskie Centrum Nauki**

19:00- **Free program in Szczecin, individual discussions**



# Chapter 2

## Abstracts

### **Scope of the GNC24 meeting: Galactic nuclei in the cosmological context** [Michal Zajaček](#) (Masaryk University)

**Abstract:** An introductory talk intended to introduce the topics discussed at the *Galactic nuclei in the cosmological context* workshop. I will provide an overview of our attempts to use type I AGN for constraining cosmological parameters. In particular, I will discuss the established relations – radius-luminosity ( $R - L$ ) and X-ray luminosity-UV luminosity ( $L_X - L_{UV}$ ) correlations – and analyze their success in standardizing quasars. Moreover, I will touch the topics of the evolution of galactic nuclei across the cosmic history.

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### **From small inhomogeneities of cosmic microwave background to galaxies, stars and planets** [Ewa Szuszkiewicz](#) (CASA\* and Institute of Physics, University of Szczecin)

**Abstract:** The scope of this talk is to give an overview about the state-of-the-art of our understanding of habitable worlds, providing a unique view on this topic by a truly interdisciplinary team of researchers. A special focus will be on astronomical aspects of habitability, which are often kept quiet. We will show how the questions about habitability should be addressed at different scales: from the cosmological scale to the scale of a single planet. We will discuss how the processes acting at different levels interact with each other and what is the result of this interaction, as far as habitability is concerned. In particular, we will indicate a way to make further progress and stimulate collaborative work in finding the solutions to fundamental questions.

## 2.1 History & Architecture session

### **History and architecture of Szczecin** [Michal Rozenberg](#) (Doctoral School, University of Szczecin)

**Abstract:** In this contribution I will focus on the presentation of the history of the city of Szczecin itself and the Pomeranian region, which is currently divided between Poland and Germany. It is



Figure 2.1: Three of Szczecin roundabout squares (Plac Szarych Szeregów, Plac Odrodzenia, and Plac Grundwaldzki) are reminiscent of the Orion belt stars (Alnitak, Alnilam, Mintaka), close to which the Celestial Equator is projected.

the life on the border area and at the same time near the Baltic Sea that has most influenced the history of the town. The contribution also includes an exposition of the most important facts from the field of architectural history and a highlighting of the peculiarities and transformations of urban architecture in Szczecin. The author defines four main areas of the city with different architecture, which was shaped at the turn of the century. Szczecin is also special in that the core of the city does not form a continuous unit today. Several historic buildings are located outside the centre. Even today, Szczecin is characterised by its unique central part, which has preserved its unique urban form from the turn of the 19th and 20th centuries.

## 2.2 AGN session I.

### Prospects for using AGN from the LSST data to cosmology

Bożena Czerny (CFT PAS, Warsaw)

**Abstract:** I will summarize the prospects of the line delay measurements from photometric LSST data from the Main Survey and from the Deep Drilling Fields.

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### Jet precession & Supermassive Binary Black Holes

Silke Britzen (MPIfR)

**Abstract:** Galaxy mergers in our Universe should produce giant supermassive binary black holes and we should find double black holes at the very center of Active Galactic Nuclei. In the future, the Next Generation Event Horizon Telescope (ngEHT) will have the sharpest view zooming in towards these objects. The NANOGrav 15 yr data already seem to be consistent with a low-frequency gravitational-wave background from ancient massive black hole mergers. How do we identify the

best candidates for close pairs which will merge in the near future? What are the telltaling signatures and patterns to look for? I will present and discuss our most recent results for the so far best supermassive binary black hole candidate OJ 287 and some other suspects.

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### **Quasi-periodic variability of XRB and AGN - Lense-Thirring precession model**

[Piotr Życki](#) (Nicolaus Copernicus Astronomical Center, Warsaw)

**Abstract:** I will present the Lense-Thirring precession model for the quasi-periodic X-ray variability of X-ray binary stars and active galaxies.

## **2.3 AGN session II.**

### **Measuring Quasar Accretion Disc Sizes with the LSST**

[Francisco Pozo Nunez](#) (Heidelberg Institute for Theoretical Studies)

**Abstract:** The Legacy Survey of Space and Time (LSST) at the Vera C. Rubin Observatory will monitor thousands of quasars using the Deep Drilling Fields (DDF) across six broadband filters over a decade. We use photometric reverberation mapping to measure the radial extent of the accretion disk (AD) by analyzing the time delays between the light curves. This task is challenging because the light curves may also contain contributions from the broad line region in the form of lines and diffuse continuum emission. Furthermore, the inherent challenges posed by time sampling restrictions (observational strategies) significantly complicate the recovery of time delays. This presentation will cover results from simulated light curves tailored to specific LSST cadences, examining the precision of delay measurements and their implications for the AD size-luminosity relationship and the potential use of quasars as standard candles.

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### **Exploring AGN Variability and Cosmological Implications: Photometric Reverberation Mapping of H-alpha emission line in Nearby Seyfert Galaxies**

[Catalina Sobrino Figaredo](#) (University of Haifa)

**Abstract:** This study conducts photometric reverberation mapping (PRM) on the H $\alpha$  emission line in nearby Seyfert Galaxies. We introduce a formalism to determine time delays in PRM, which simultaneously provides information on the time delay and an estimation of the contribution of the emission line within the photometric narrow-band filter. We present results for a sample of 80 AGN, some of them over a decade-long observing period, enabling the detection of intrinsic AGN changes across different observation seasons. Utilizing the flux variation gradient (FVG) method, we estimate AGN color, host-subtracted luminosities, and identify possible Changing Look (CL) AGNs within our sample. Additionally, spectral analysis allows us to estimate black hole masses and accretion rates. Our results refine the current H $\alpha$   $r_{\text{BLR}} - L$  relation, which serves as a candidate for cosmological distance calibration. We explore the R-L relation across different AGN properties, such as AGN color and accretion rate and we discuss the potential implications of the  $r - L$  calibration using the H $\alpha$  emission line.

## 2.4 Nuclear Star Clusters session

### Will UFOs show us SMRIs?

Petra Suková (Astronomical Institute of the Czech Academy of Sciences)

**Abstract:** Recently, a previously quiescent nearby galactic nucleus, ASASSN-20qc, went to an outburst during which it has shown quasi-periodic ultra-fast outflows (UFOs) with changing column density every cca 8 days. Different physical mechanisms have been proposed to explain such behaviour, with the most promising scenario being the smaller, probably intermediate-mass black hole, orbiting the primary supermassive black hole at the distance of about hundred gravitational radii of the primary. The secondary black hole is punching through the accretion flow launching fast outflowing blobs of gas, which are causing repeating absorption events. In general, during an ongoing small mass ratio inspiral (SMRI), the secondary is perturbing the accretion flow on the primary SMBH causing different temporal and spectral departures from the stationary flow. Searching for these typical signatures of SMRI in EM all-sky surveys may reveal possible targets for future GW observatories, such as LISA or Einstein telescope.

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### Modelling the coexistence of a nuclear cluster and a SMBH surrounded by a massive torus

Vladimír Karas (Astronomical Institute of the Czech Academy of Sciences)

**Abstract:** We have updated our modelling work of a gravitating gaseous/dusty disk or a torus around a supermassive black hole. Our main objective is to demonstrate that interaction of nuclear stars with the toroidal perturbation can increase the rate of orbital decay of stellar trajectories by setting some stars on eccentric orbits. Cooperation between the gravitational field of the disc and the dissipative environment then provides a mechanism explaining the origin of stars that become bound tightly to the central black hole. We examine this process as a function of the black hole mass and conclude that it is most efficient at the lower end of SMBH mass interval. Members of the cluster experience the stage of orbital decay via collisions with the accretion disc and by other dissipative processes, such as tidal effects, dynamical friction and the emission of gravitational waves. Mutual interaction between stars and the surrounding environment establishes a non-spherical shape and anisotropy of the stellar system; in some cases, the stellar sub-system acquires a ring-type geometry. Stars of the nuclear cluster may undergo tidal disruption events as they plunge below the critical radius near the supermassive black hole.

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### Red giant stars' deficiency near the Galactic center as a consequence of the enhanced galactic jet activity in the past

Petr Kurfürst (Masaryk University)

**Abstract:** Relatively recently, a new analytical theory has been proposed to explain the long-standing problem of missing red giants near the center of our Galaxy by ablation of the upper layers of these stars as they pass through the relativistic galactic jet. Using a state-of-the-art hydrodynamical code, we simulate the passage of a red giant through a galactic jet numerically. We consider a star that is initially in hydrostatic equilibrium, with polytropic profiles of various state variables.



We further let the outer layers of the star evolve as a free system, where deviations from the initial equilibrium are incorporated into a new, no longer fully equilibrium state, while the inner region of the star is continuously damped to achieve a hydrostatic equilibrium throughout the simulation. We then evaluate the amount of mass that can be removed from the star as it passes through differently parameterized galactic jets and also for different orbital distances from the galactic center. Our ultimate goal at this stage is to evaluate as realistically as possible the amount of mass that can be ablated from red giants in this way during many repeated passages through the galactic jet and extrapolate the effect of the loss of these layers on further evolution of this type of stars.

## 2.5 Galactic nuclei evolution & AGN feedback session

### High-redshift AGNs & galaxies behind the lensing cluster Abell 2744

[Orsolya Kovács](#) (Masaryk University, Brno)

**Abstract:** Abell 2744 serves as a gravitational lens to the high-redshift universe in JWST observations. The *UNCOVER* survey reported the detection of nearly twenty  $z > 9$  galaxies behind this lensing cluster. Additionally, an unexpected new population of galaxies, referred to as “little red dots” was discovered in the JWST data behind Abell 2744, at  $3 < z < 9$ . Using deep Chandra X-ray observations, we followed up on these high-redshift galaxies and searched for X-ray emission associated with their central BHs.

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### Observations of AGN-induced dynamics of hot galactic and cluster atmospheres

[Norbert Werner](#) (Masaryk University, Brno)

**Abstract:** I will discuss indirect and direct measurements of AGN-induced velocities in hot galactic and cluster atmospheres. The indirect measurements of atmospheric dynamics include measurements of resonance scattering, surface brightness fluctuations, the kinematic Sunyaev-Zeldovich effect, and spectroscopically measured velocities of emission line nebulae, which are believed to have cooled from the hot atmospheric gas. High resolution X-ray spectroscopy of the Perseus Cluster with Hitomi and recently with XRISM provided direct measurements of gas velocities from the widths and shifts of emission lines. Future X-ray missions will bring significant progress in our understanding of AGN-induced dynamics of diffuse baryons, which appears to affect the evolution of structure on the largest scales in the Universe.

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### Gravitational lensing from clusters of galaxies to test Disformal Couplings Theories

[Saboura Zamani](#) (University of Szczecin)

**Abstract:** In this talk, we investigate the potential existence of a non-minimal coupling between dark matter and gravity using a compilation of galaxy clusters. We focus on the disformal scenario of a non-minimal model with an associated coupling length “L”. Within the Newtonian approximation, this model introduces a modification to the Poisson equation. We have tested the model by

examining strong and weak gravitational lensing data from the *CLASH* survey. We used a Markov Chain Monte Carlo code to explore the parameter space using two statistical approaches to analyze our results: standard marginalization and profile distribution. The profile distribution method helps to address certain volume effects in the posterior distribution and shows lower concentrations and masses in the non-minimal coupling model compared to general relativity. In addition, our investigation revealed a remarkably strong correlation between the coupling constant “L” and the standard Navarro–Frenk–White scale parameter  $r_s$ , indicating a significant relationship between these two parameters.

## 2.6 Space weather & Astrobiology session

### Space weather modelling at KU Leuven: model chains, limitations, and user needs

[Michaela Brchnelová](#) (KU Leuven)

**Abstract:** Space weather forecasting has been gaining on importance as our society has been more and more reliant on technology sensitive to space weather effects, such as satellite services, power grids and radio-communication. KU Leuven has been coordinating the Virtual Space Weather Modelling Centre included in the ESA’s Space Situational Awareness programme, which currently includes over 30 different models from various institutions that are coupled to each other into a modelling toolchain to provide the end-users with flexibility in terms of the desired simulation outputs, the achievable accuracy and the required run time. Several of these models are developed and maintained at KU Leuven, and their operation and limitations will be introduced in this talk. In addition, in collaboration with the Royal Observatory of Belgium, we also train and work with end-users such as the military, who have specific needs regarding space weather products and with whom we often notice gaps in communication and mutual understanding. In this talk, I will thus also shortly address these gaps and what we can do better as a community to bridge them.

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### Human space travel: an astrobiologist’s point of view (popular talk)

[Franco Ferrari](#) (CASA\* and Institute of Physics, University of Szczecin)

**Abstract:** Space offers to humanity many opportunities and at the same time poses several threats, not only physical, like ionizing radiation and microgravity, but also societal and psychological. It may also be argued that the constant background of ionizing radiation from cosmic origin actively influences the evolution of life on a planet. After a brief introduction on these topics, an experiment examining the possibility of enhancing the adaptability of budding yeast (*Saccharomyces cerevisiae*) to microgravity conditions using genome editing techniques will be presented. *S. cerevisiae* is a well-known model organism. Its genome can be easily manipulated in the laboratory and it shares common cell properties with plants, animals, and human beings. Therefore, the research outcome is not limited to yeast, but is of a fundamental nature. The implications of the experiment on space exploration will be discussed.

## 2.7 Low-luminosity galactic nuclei session

### Broad-band spectral modeling of M87 nucleus

[Agnieszka Janiuk](#) (CFT PAS, Warsaw)

**Abstract:** We model the broad-band spectrum of M87 with a 2-step method. First, we apply the ADAF model involving the analytical solutions of the hydrodynamical equations using the phenomenological  $\alpha$ -prescription for viscosity and assuming some value of the plasma magnetization. We then set the electron temperature based on the results obtained from the ADAF model, which includes a detailed treatment of the electron energy balance, and we adopt the magnetic field distribution as resulting from the fully GR MHD simulation. Thus, we question a common practice in radiation calculations of such models, which is to set  $T_e$  after running the simulation, as a function of local plasma parameters. This popular parameterization, used in particular by the EHT Collaboration, and referred to as the  $R - \beta$  model, may yield unrealistically high values of  $T_e$ . Our broad-band model reproduces well the observed data in the quiescent phase of M87\* reported by Prieto et al. (2016), and the quasi-simultaneous multi-wavelength campaign in 2017.

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### Candidate Young Stellar Objects in the S-cluster

[Maria Melamed](#) (University of Cologne)

**Abstract:** The Galactic Center provides a unique opportunity to observe galactic cores, objects in the close proximity to a supermassive black hole (SMBH), and star formation channels that exhibit imprints of this peculiar environment. This habitat hosts, in addition to the SMBH Sgr A\*, a surprisingly young cluster with the so-called S-stars. These stars orbit the SMBH on timescales of a few years with thousands of km/s. While the presence of high-velocity stars in the S-cluster already imposes a variety of scientific questions, the observation of several bright  $L$ -band emission sources has resulted in a rich discussion of their nature. The detection of a prominent Doppler-shifted Br $\gamma$  line accompanies most of these sources that seem to be embedded in a dusty envelope. With the radiative-transfer model HYPERION, we find strong indications of the presence of a stellar low-mass population embedded in the S-cluster. We revisit this intriguing cluster and its dusty members that orbit the supermassive black hole Sgr A\* on bound Keplerian trajectories. Among these cluster members, there is one source that initiated the studies of this analysis: G1. Therefore, the talk will discuss the source G1 in more detail and show new results using the longest time and widest waveband baseline used for its analysis based on SINFONI and NACO observations mounted at the VLT (Chile). Our results strongly suggest a stellar nature of G1 and challenge alternative explanations. We find that the flux density of G1 in the NIR and MIR resembles a spectral energy distribution of a Class I YSO, which contributes to the “Paradox of Youth”.

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### Evolution of Disk-like Structures in the Galactic Centre

[Myank Singhal](#) (Charles University in Prague)

**Abstract:** In this work, we present an understanding of the complex mechanisms that govern the evolution of orbits in the Galactic Centre. Through N-body simulations, we have gained crucial insights into the evolution of disk-like structures in the Galactic Centre. We see that post-Newtonian

corrections and perturbative effects are critical in stabilizing these structures. In their absence, these structures would disintegrate due to vector resonance relaxation. Additionally, our research has demonstrated how these disk-like structures can split and create multiple disks with different properties, which could explain both clockwise and counterclockwise disks, as well as the highly debated disk-like structures in the S-star cluster. Our findings shed light on the intricate interplay between gravitational forces from different bodies that shape the dynamics of stars, dusty sources, and compact stellar remnants in the Galactic Centre, providing an important theoretical contribution to the field.

## 2.8 Galactic nuclei/AGN feedback session I.

### Statistics of Quasi-periodic Eruptions

[Martin Mondek](#) (Masaryk University)

**Abstract:** Quasi-periodic eruptions (QPEs) are new UV/X-ray transient phenomena in galactic nuclei that change on very short timescales - hours or days. Variability occurs practically everywhere - in timing properties, luminosities, flare shapes, and so on. In this presentation, we visualize the basic properties of the sources that the X-ray satellites detected so far. We attempt to correlate some of those properties, such as the peak luminosity, duty cycle, central black hole mass, etc. Periodograms are used here to analyze the period. We adopted a physical model of a system that tries to explain the nature of QPE sources and simplified it to create our own artificial light curves. Finally, we forecast what the typical timescale of the QPE phenomenon is.

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### Studying radio-mechanical AGN feedback with X-ray cavities

[Tomáš Plšek](#) (Masaryk University)

**Abstract:** The study of radio-mechanical AGN feedback provides powerful insights into the energetics of early-type galaxies and galaxy clusters. The total energy released during individual AGN outbursts has been imprinted into jet-inflated bubbles (X-ray cavities) and can be derived by estimating the total cavity extent. To this day, studies of X-ray cavities focused mainly on individual objects, and the cavity size estimates were ultimately based on visual inspection of noisy X-ray images. We are systematically studying an extensive sample of  $\sim 150$  galaxies and clusters containing X-ray cavities. We will present preliminary results of this analysis showing correlations with other galaxy properties (SMBH mass, thermal state of hot atmosphere, etc.) and comparing individual cavities of multi-cavity systems. Furthermore, we will present a novel machine-learning method called the Cavity Detection Tool (CADET), developed to allow an automated and reproducible study of X-ray cavities.

## 2.9 Galactic nuclei/AGN feedback session II.

### Differencing between quiescent and flaring states of blazars using threshold autoregressive models

[Klaudia Kowalczyk](#) (Nicolaus Copernicus University in Toruń)

**Abstract:** Blazars are a unique class of active galactic nuclei (AGNs) hosting relativistic jets that point almost directly at the observer. These objects are observed in the whole electromagnetic spectrum, from radio waves to very high energy gamma-ray photons. They are known to be highly variable sources in all energy bands, particularly in gamma rays, in which they exhibit powerful flares. The Fermi Gamma-ray Space Telescope has been observing blazars' light curves for almost 15 years and has proven to be an excellent tool for studying their variability. In my work, I explore the variability of blazars using novel methods for astronomical analysis that were not commonly used in this field before. The self-exciting threshold autoregressive (*SETAR*) model proved to be a reliable way to differentiate quiescent states from flares based on the designated threshold.

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## Chemical abundances along the Quasar Main Sequence

Alberto Floris (CFT PAS, Warsaw)

**Abstract:** Active Galactic Nuclei (AGN) are complex astrophysical phenomena, characterized by numerous properties that are not yet fully understood. The Main Sequence (MS) of quasars, a parameter space defined by the FWHM of  $H\beta$  and the ratio of the intensity of FeII emission to  $H\beta$  in the optical spectrum, has emerged as a highly effective tool for organizing observational and physical properties of Type-I AGN. In this study, we present multiple measurements of metallicity for the Broad Line Region (BLR) gas, from both new and previously published data, to address the long-standing conundrum of the enhanced metallicity of the BLR gas. By confronting the measurements associated with  $\sim 10$  diagnostic ratios sensitive to metallicity, density, and ionization parameter with the corresponding results from CLOUDY photoionization simulations, we demonstrate a consistent trend of metallicity along the MS. The trend involves an increase from sub-solar metallicity in correspondence with extreme Population B (weak FeII emission, large  $H\beta$  FWHM) to metallicity several times the solar value in correspondence with extreme Population A (very strong FeII optical emission, narrower  $H\beta$  profiles). If the very high metallicity (roughly 10 times above the solar metallicity) gas is expelled from the sphere of influence of the central black hole, as indicated by the widespread evidence of nuclear outflows and disk wind in the case of sources radiating at high Eddington ratio, then it is possible that the outflows from quasars play a role in chemically enriching their respective host galaxies. Additionally, the identification of a metallicity trend along the quasar MS hints to the possibility of an evolutionary path of AGN along the MS, with extreme Population A objects being the youngest and Population B AGN being the oldest.

## 2.10 Concluding remarks and the discussion

### Meeting summary and closing remarks

Michal Zajaček (Masaryk University, Brno)

**Abstract:** I will provide a concise summary of GNC 2024 meeting, highlighting key results, ideas, and the legacy. I will also try to outline future prospects for collaborations and meetings.



Figure 2.2: Stawa Młyny in Swinoujście.

# Chapter 3

## Practical information & Social Program

### 3.1 Language

The official language in Poland is Polish. It uses the Latin alphabet. Many people can speak at least one foreign language, usually English or German. The language of Science is English. We will use it for all lectures and in all scientific discussions.

### 3.2 Currency

In Poland, for financial transactions and payments, the official currency is the Polish zloty. As of now, the EURO-Zloty exchange rate is approximately,

$$1 \text{ EURO} \approx 4.25 \text{ Zloty}$$

### 3.3 Venue and how to get there

The workshop *Galactic nuclei in the Cosmological Context* will be hosted by the **Doctoral School of the University of Szczecin**, <https://szkoladoktorska.usz.edu.pl/en/home-2/>. It is located on the Adama Mickiewicza Street no. 16 (see the building photo below). There are different ways to reach the destination.

When you travel to the Doctoral School by public transport, there are essentially two ways:

- From the city center (Brama Portowa – Harbour Gate), one can take trams number 7 and 9 to the stop Wawrzyniaka 12 or take tram number 1 to the stop Felczaka 12.
- From the Szczecin Main Railway Station (Szczecin Główny), one can take tram 9 from the stop Sowinskiego 12 to Wawrzyniaka 12 or tram 1 to Felczaka 12.



Figure 3.1: Venue building on Adam Mickiewicz Street 16 (left panel) and the lecture room (right panel).

### 3.4 Public transport

There are trams and buses operated by the Szczecin Public Transport - Zarząd Dróg i Transportu Miejskiego <https://www.zditm.szczecin.pl/en>. The connections can also be easily found e.g. on Google Maps. Tickets can be bought at the stops or on the trams using credit cards.

### 3.5 Social Program

We have scheduled several social events between June 3rd and June 6th. These are in chronological order:

- **Monday (June 3rd): 19:00, Welcome Drink and Dinner** at the Nowy Browar Szczecin, *Partyzantów 2*,
- **Wednesday (June 5th): 9:00-20:00 Sightseeing day: Visit of Świnoujście/Swinemünde at the Baltic Sea**
- **Thursday (June 6th): 16:30-18:00, Morskie Centrum Nauki–Maritime Science Center**, *street Nad Dunczyka 1*
- lunch menus on Tuesday and Thursday between 12:00 and 14:00 at the **Restaurant Artisan**, *al. Piastów 74*

### 3.6 Code of Conduct

All the participants are asked to behave respectfully towards others at all times. We will follow the code of conduct according to the International Astronomical Union <https://www.iau.org/static/archives/announcements/pdf/ann16007a.pdf>.



# Chapter 4

## Participant list

1. **Michal Zajaček** • Masaryk University, Brno
2. **Bożena Czerny** • Center for Theoretical Physics, Polish Academy of Sciences, Warsaw
3. **Vladimír Karas** • Astronomical Institute of the Czech Academy of Sciences
4. **Petra Suková** • Astronomical Institute of the Czech Academy of Sciences
5. **Norbert Werner (online)** • Masaryk University, Brno
6. **Silke Britzen** • Max Planck Institute for Radioastronomy, Bonn
7. **Martin Mondek** • Masaryk University, Brno
8. **Saboura Zamani** • University of Szczecin
9. **Alena Vanžurová** • Masaryk University, Brno
10. **Enrico Laudato** • University of Szczecin
11. **Mateusz Słomiany** • University of Szczecin
12. **Maria Melamed** • University of Cologne
13. **Shafqat Ali** • University of Szczecin
14. **Myank Singhal** • Charles University in Prague
15. **Agnieszka Janiuk** • CFT PAS, Warsaw
16. **Joseph Saji** • CFT PAS, Warsaw
17. **Alberto Floris** • CFT PAS, Warsaw
18. **Vincenzo Salzano** • University of Szczecin
19. **Piotr Życki** • Nicolaus Copernicus Astronomical Center, Warsaw

## Chapter 4 Participant list

20. **Ewa Szuszkiewicz** • CASA\* and Institute of Physics, University of Szczecin
21. **Petr Kurfürst** • Masaryk University, Brno
22. **Anna Wójtowicz** • Masaryk University, Brno
23. **Franco Ferrari** • University of Szczecin
24. **Michaela Brchnelová (online)** • KU Leuven
25. **Klaudia Kowalczyk** • Nicolaus Copernicus University in Toruń
26. **Kazuma Ishio** • Nicolaus Copernicus University in Toruń
27. **Catalina Sobrino Figaredo** • University of Haifa
28. **Francisco Pozo Nunez** • Heidelberg Institute for Theoretical Studies (HITS)
29. **Tomáš Plšek** • Masaryk University
30. **Michał Rozenberg** • University of Szczecin
31. **Paulina Małkowska** • University of Szczecin
32. **Tomasz Denkiewicz** • University of Szczecin
33. **Jean-Paul Breuer** • Masaryk University, Brno
34. **Orsolya Kovács** • Masaryk University, Brno