Evolution of MHD Torus and magnetically driven mass outflows around spinning AGN

Type: Poster

Primary Author: MD Ramiz Aktar

Co-authors: Kuo-Chuan Pan, Toru Okuda

We perform axisymmetric two-dimensional magnetohydrodynamic simulations (MHD) to investigate accretion flows around spinning supermassive black holes (SMBHs). To mimic the space-time geometry of black holes, we consider effective Kerr potential (Dihingia et al., 2018), and the mass of the black holes is $10^8 M_\odot$. We initialize the accretion disc with a magnetized torus by adopting the toroidal component of the magnetic vector potential. The initial magnetic field strength is set by using the plasma beta parameter (β), i.e., the ratio of the gas pressure to the magnetic pressure. We observe self-consistent turbulence generated by magnetorotational instability (MRI) in the disc. The MRI turbulence transports angular momentum in the disc, and the angular momentum distribution becomes near the Keplerian distribution. We investigate the effect of the magnetic field on the dynamics of the torus and associated mass outflow from the disc around a maximally spinning black hole (a_k=0.99). We find that mass outflow rates are significantly enhanced with the increased magnetic field in the disc. We also investigate the effect of black hole spin on the magnetized torus evolution. However, we have not found any significant effect of black hole spin on mass outflows in our model. Finally, we discuss the possible astrophysical application of our simulation results.

A Closer Look: Modeling Emission in M87 Down to the Horizon-Scale with Positrons

Type: Invited Talk

Primary Author: Richard Anantua

Co-authors:Roger Blandford, Razieh Emami, Angelo Ricarte

With the advent of sub-mm imaging of black hole shadows by the Event Horizon Telescope starting in 2019 with M87*, we are now in a position to infer physical mechanisms powering systems such as M87 (including its relativistic jet) down to the horizon-scale using phenomenological models. First, a self-similar, stationary, axisymmetric jet model based on a force-free flow in a High Accuracy Relativistic Magnetohydrodynamics (HARM) jet simulation is used to generate Stokes maps at Very Long Baseline Array (VLBA, 43 GHz) and Event Horizon Telescope (EHT, 230 GHz) scales– varying plasma content from ionic (e-p) to pair (e-e+). Emission at the observed frequency is assumed to be synchrotron radiation from electrons and positrons, whose pressure is set to be constant fractions of the local magnetic pressure. The cleanest observational signatures predicted are the vanishing of intrinsic circular polarization in V/I maps and in polarized spectra for positron-rich jets. Positrons are then incorporated into the general relativistic ray tracer IPOLE to display positron effects in HARM simulations within ~10 gravitational radii from the black hole. Models of magnetized plasma in the M87 jet/accretion flow/black hole (JAB) system based on turbulent heating and deviations from the equipartition of particle and magnetic energies reveal a stark dichotomy in polarization signatures between standard and normal evolution (SANE) and magnetically arrested disk (MAD) accretion modes due to positron-modulated Faraday effects. The inclusion of electrons, positrons and protons in our radiative transfer pipeline thus provides a powerful probe of the composition of JAB systems.

Astrophysical Black Holes — Some Attractive, Powerful, Illuminating and Exciting Questions

Type: Invited Talk

Author: Roger Blandford

In this introductory talk, I will rehearse some of the astrophysical questions that have been posed by recent observations of massive and stellar black holes, paying special attention to “frontier” science associated with mm VLBI, gravitational radiation, VHE gamma rays and neutrinos, UHE cosmic rays and in the time domain. Future opportunities using new facilities, including JWST, will be previewed.

The Observation of the Brightest GRB 221009A by LHAASO

Type: Invited Talk

Author: Zhen Cao on behalf of LHAASO

LHAASO observed GRB221009A, as the brightest GRB, with it nearly in the middle of the FoV. The onset of the afterglow in TeV band was first time observed by measuring the flux from the GRB since T0 set by a precursor. This enables 1) Determining the start time of the afterglow T* ~226 s after T0; 2) Setting the most strict limit on the prompt emission in TeV band ~ 10^(-5); 3) Estimating the initial bulk Lorentz factor Γ_0 of the ejecta ~ 440; 4) Measuring the jet break shortly after the onset indicating a narrow jet structure observed ever; 5) Further investigations for more GRB features, including the most energetic photons.

Hunting down stellar-mass black-holes with Gaia

Type: Contributed Talk

Primary Author: Chirag Chawla

Co-authors: Sourav Chatterjee, Katelyn Breivik

Understanding the connection between the properties of black-holes (BHs) and their progenitors is interesting in many branches of astrophysics. Traditional methods such as detection through X-ray, radio, or gravitational-wave emission are sensitive towards a small subset of all BH binaries expected to form in nature. In my talk I will explore the exciting possibilities for detecting BHs in detached binary systems with luminous companions (LCs) via astrometric and photometric measurements. We create highly realistic models of BH-LC binaries expected to be there at present in the Milky Way (MW) using the binary population synthesis code COSMIC for two adopted supernova models. Taking into account Gaia's astrometric precision, spectroscopic resolution, and interstellar extinction and reddening, we find that Gaia in its 10 year mission should detect around 30-300 BH candidates. These potentially detectable BHs constitute a set complementary to those detected by other traditional methods. Furthermore, since the LC's properties, such as age and metallicity, can be constrained relatively easily, and it is expected that the BH's progenitor must have had the same zero-age properties as the LC, if detected in large numbers as our models suggest, for the first time, we will be able to constrain the highly uncertain map connecting BH properties with those of their progenitors. With Gaia's third data release (DR3), several dormant compact-object (CO) candidates have been detected. I will discuss how well our predictions match with the recently detected dormant candidate CO properties. Finally, I will also explain why the DR3 candidates consist mainly of white dwarfs and neutron stars, but not BHs in large numbers as was predicted by several theoretical studies including ours.

Spectra and light curves of the radiative reprocessing in an outflow

Type: Poster

Author: Chun Chen

Co-author: Rong-Feng Shen

The radiation reprocessing model, in which an optically-thick layer or outflow absorbs the high-energy emission from a central source and re-emits in longer wavelengths, has been frequently invoked to explain some optically bright transients such as tidal disruption events (TDEs) and fast blue optical transients (FBOTs). Previous studies on this model did not take into account either the time evolution of the radiation signature or the frequency-dependent opacity. We study the radiative reprocessing in a time-dependent, steady-state and spherical outflow composed of pure hydrogen gas. Frequency-dependent bound-free, free-free, bound-bound and electron scattering opacities are considered. We present the analytical and numerical results of the emitted spectrum and the light curve. The results show that although the outflow is highly ionized, the bound-free transition in the outflow cannot be neglected due to its large cross-section. The results also show that the emitted spectrum has a significant extension in the NIR band, and evolves as $L\nu \propto \nu$^0.5. The model predicts light curves at different wavelengths. We discuss the effects of the injected luminosity, and the mass and velocity of the outflow on the results. We apply our model to the typical FBOT AT2018cow.

Tidal Stripping of a White Dwarf by an Intermediate-Mass Black Hole

Type: Contributed Talk

Primary Authors: Jin-Hong Chen

Co-authors: Shang Fei Liu, Rong Feng Shen

During the inspiralling of a white dwarf (WD) into an intermediate-mass black hole (~10^{2-5} $M_{\odot}$), both gravitational waves (GWs) and electromagnetic (EM) radiation are emitted. Once the eccentric orbit's pericenter radius approaches the tidal radius, the WD would be tidally stripped upon each pericenter passage. The accretion of these stripped mass would produce EM radiation. It is suspected that the recently discovered new types of transients, namely the quasi-periodic eruptions and the fast ultraluminous X-ray bursts, might originate from such systems. Modeling these flares requires a prediction of the amount of stripped mass from the WD and the details of the mass supply to the accretion disk. We run

Why are LIGO/Virgo black holes so massive?

Type: Contributed Talk

Primary Author: Xian Chen

Measuring the mass and distance of a gravitational wave (GW) source is a fundamental problem in GW astronomy. The issue is becoming even more pressing since LIGO and Virgo have detected massive black holes that in the past were thought to be rare, if not entirely impossible. The waveform templates used in the detection are developed under the assumption that the sources are residing in a vacuum, but astrophysical models predict that the sources could form in gaseous environments, move with relatively large velocity, or reside in the vicinities of supermassive black holes. In my talk, I will show how the above environmental factors could distort the GW signals and result in a biased estimation of the physical parameters, such as mass and distance. In particular, I will highlight the ubiquity of such a bias among the LIGO/Virgo sources formed in active galactic nuclei. If not appropriately accounted for, the above bias may alter our understanding of the formation and evolution of the black holes found via gravitational waves.

Simulating Jet/Outflow Behavior in Massive Galaxies: A New Black Hole Feedback Model in NIHAO Simulations

Type: Poster

Primary Authors: Changhyun Cho

Co-author Andrea Maccio

Our study introduces a new algorithm for black hole feedback in the Numerical Investigation of a Hundred Astrophysical Objects (NIHAO) project of galaxy simulations. We present two modes of black hole feedback based on both theoretical models and observational evidence highlighting the importance of kinetic AGN outflows in massive galaxies. To account for high Eddington accretion rates, we implement a thermal feedback model that heats the surrounding gas by converting the accreted rest-mass energy. For low-accretion rates, we develop a new kinetic feedback model that converts accreted energy to pure momentum, imparting it to the nearby gas surrounding the supermassive black hole in a direction perpendicular to the black hole spin to simulate jet/outflow behavior. This allows us to study high-mass, elliptical galaxies, where feedback from the central black hole significantly affects their evolution. In this presentation, we focus on testing and calibrating the algorithms against the stellar mass versus halo mass relation and the black hole mass versus stellar mass relation to demonstrate the effectiveness of our models.

Active Galactic Nuclei Feedback : From Cosmological Simulation to Observation

Type: Contributed Talk

Primary Author: Rudrani Kar Chowdhury

Co-authors: Suchetana Chatterjee, Jane Dai, Craig Sarazin

Observations suggest that feedback from Active Galactic Nuclei (AGN) plays an important role in the evolution of large scale structures of the universe. However, the exact physics of coupling the feedback energy to their surrounding medium is still not well understood. In this talk I will try to explain our work to investigate different modes of AGN feedback and their effects on the surrounding gas as well as host galaxies and dark matter halos by analyzing diffuse X-ray emission from galaxy groups and clusters. Starting with careful investigation of different scaling relations between supermassive black holes (SMBH) and host halo properties using cosmological simulation, we continue to model X-ray emission from simulated galaxy clusters with the help of Astrophysical Plasma Emission Code (APEC). Finally, we perform synthetic observation of the Chandra X-ray telescope of these systems using a ray-tracing simulator Model of AXAF Response to X-rays (MARX) to compare them with actual observations. Our results conclusively establish the impact of AGN feedback on their ambient medium. Besides, we show the importance of jet and X-ray mode of AGN feedback together with their detection probability at different redshifts with Chandra and propose to continue the search with upcoming X-ray missions such as Athena and XRISM.

Looking for Physics in the Weather: 30 Years of Gamma-Ray Blazar Observations

Type: Invited Talk

Author: Paolo Coppi

The launch of the Compton Gamma-Ray Observatory in 1991 revealed that the powerful relativistic outflows ("jets") produced by accreting supermassive black holes are in fact some of the most prodigious emitters of gamma-rays in the Universe. Even accounting for likely relativistic beaming and boosting effects, this gamma-ray emission can represent a significant of the black hole's accretion power. Exactly how a black hole manages this is still not well understood, but it is clear that the underlying physical conditions and processes are among the most extreme we **know** of. Because this gamma-ray emission is sporadic and highly variable, it has been termed by some as "weather" that obscures more fundamental physics. There is some truth to this, but I will argue that we have nonetheless made significant progress, both observational and theoretical, since the first gamma-ray observations of blazars. I will give an overview of the outstanding issues in the study of high-energy emission from blazars and of our future prospects for tackling them.

Temperature properties in magnetized accretion flow around black holes

Type: Poster

Primary Author: Indu Kalpa Dihingia

We perform general-relativistic magnetohydrodynamic (GRMHD) simulations around the Kerr black hole in a two-temperature paradigm. The goal is to understand the physics around them and extract more accurate physical information from astrophysical observations. Keeping that in mind, we developed a self-consistent numerical formalism to study electron thermodynamics in GRMHD by incorporating heating, radiative cooling, and coupling between electrons and protons. In the talk, I will explain the temperature properties of electrons and ions in the accretion flow around Kerr black holes. We study the role of radiative cooling in both geometrically thick and thin accretion disc scenarios. The temperature profiles of different components show significantly different natures in both physical scenarios. The talk will also explore the inconsistency due to the use of temperature scaling relations and their consequences in near-horizon observations in Sgr A* and M87.

A Dark Matter Probe in Accreting Pulsar-Black Hole Binaries

Type: Poster

Primary Author: Qianhang Ding

Co-authors: Ali Akil

The accretion of dark matter (DM) into astrophysical black holes slowly increases their mass, and this mass accretion depends on DM models and model parameters. If this mass accretion effect can be measured accurately enough, it is possible to rule out some DM models, and, with the sufficient technology and the help of other DM constraints, possibly confirm one model. We propose a DM probe based on accreting pulsar-black hole binaries, which provides a high-precision measurement on binary orbital phase shifts induced by DM accretion into black holes, can help rule out DM models and study the nature of DM.

Hidden Cooling Flows in Clusters and Groups of Galaxies

Type: Contributed Talk

Author: Andy Fabian

Half of all clusters of galaxies have a cool core in which the temperature drops inward and the density rises as expected from a cooling flow. Over 20 years ago, High Resolution XMM RGS Spectra showed little evidence for the cooling flow continuing below 1 keV at the rates inferred from higher temperatures. We have now re-examined the RGS spectra of over 20 clusters and groups and 4 early-type galaxies and find that an intrinsically-absorbed (HIdden Cooling Flow) model allows for significant continuous mass cooling rates to 0.1 keV and below at the level of 15-50% of the expected rates from above 1 keV. The rates range from 1-20 Msun/yr in groups to 15 -100 in regular clusters. Several highly luminous clusters have mass cooling rates of 1000 Msun/yr or more. Where available the Far Infrared flux is compatible with that expected from X-ray absorption. AGN feedback can account for 50-85% of the reduction in mass cooling rates but the remainder is significant. We discuss these results and outline the possible fate of the cooled gas, including Very Cold Gas Clouds, Low- Mass Star Formation, outward dragging by rising bubbles and non-luminous swallowing by the central black hole.

Extreme particle acceleration at AGN jet termination shocks

Type: Contributed Talk

Authors: Gwenael Giacinti

Co-authors: Benoît Cerutti

Extragalactic plasma jets are some of the few astrophysical environments able to confine ultra-high energy cosmic rays, but whether they are capable of accelerating these particles is unknown. In this work, we revisit particle acceleration at relativistic magnetized shocks beyond the local uniform field approximation, by considering the global transverse structure of the jet. Using large two-dimensional particle-in-cell simulations of a relativistic electron-ion plasma jet, we show that the termination shock forming at the interface with the ambient medium accelerates particles up to the confinement limit. The radial structure of the jet magnetic field leads to a relativistic velocity shear that excites a von Kármán vortex street in the downstream medium trailing behind an over-pressured bubble filled with cosmic rays. Particles are efficiently accelerated at each crossing of the shear flow boundary layers. These findings support that extragalactic plasma jets may be capable of producing ultra-high energy cosmic rays. This extreme particle acceleration mechanism may also apply to microquasar jets.

Accretion flows in AGN dominated by feedback from embedded black holes

Type: Contributed Talk

Authors: Shmuel Gilbaum

Co-authors: Nicholas Stone

We present new two-fluid models of accretion disks in active galactic nuclei (AGN) that aim to resolve the long-standing problem of Toomre instability in AGN outskirts. In the spirit of earlier work by Sirko Goodman 2003 and others, we argue that Toomre instability is eventually resolved via feedback produced by fragmentation and its aftermath. Unlike past semi-analytic models, which (i) adopt local prescriptions to connect star formation rates to heat feedback, and (ii) assume that AGN disks self-regulate by star-forming, we find that feedback processes are both temporally and spatially non-local. The accumulation of many stellar-mass black holes (BHs) embedded in AGN gas eventually displaces stellar winds and supernovae as the dominant feedback source. The non-locality of feedback heating, in combination with the need for heat to efficiently mix throughout the gas, gives rise to steady-state AGN solutions that can have a Toomre parameter much greater than 1 and no ongoing star formation. We explore the implications of our two-fluid disk models for the evolution of compact object populations embedded in AGN disks, and find self-consistent solution in much of the parameter space of AGN mass and accretion rate. These solutions harbor large populations of embedded compact objects which may grow in mass by factors of a few over the AGN lifetime, including into the lower and upper mass gaps. These feedback-dominated AGN disks are significantly different in structure from commonly used 1D disk models, which has broad implications for gravitational wave source formation inside AGN.

Black holes as cosmic accelerators

Type: Invited Talk

Author: Noemie Globus

The origin of ultra high energy cosmic rays remains a mystery. It represents the challenge of finding the nature of the most powerful particle accelerators in the Universe, which exhibit collisions with center of mass energies about 100 times those attainable at the LHC. During their acceleration process, they produce high energy gamma-rays and neutrinos. These secondary messengers reveal clues about the extreme environments around stellar or supermassive black holes. I will present models of the powerful cosmic engines associated with black holes and review the possible sources candidates in light of some recent developments in Multimessenger Astrophysics.

The Gas Content and Star Formation in Quasars

Type: Invited Talk

Primary Author: Luis Ho

AGN feedback is often invoked in galaxy evolution, as a key physical mechanism to self-regulate star formation and black hole accretion. Is this mechanism truly effective? How to tell? I will describe a series of new experiments designed to use the ISM properties of quasar host galaxies to test the efficiency of AGN feedback. I will also introduce new methods to estimate the star formation rate, star formation efficiency, and ISM properties in quasar host galaxies, which are currently very poorly constrained. The ISM and star formation properties of quasars provide key insights into the role that black holes play in the lifecycle of galaxies.

Supercritical growth of seed BHs at cosmic dawn and co-evolution with host galaxies

Type: Contributed Talk

Authors: Haojie Hu

Co-authors: Kohei Inayoshi, Wenxiu Li, Zoltán Haiman, Eliot Quataert, Rolf Kuiper

Supercritical growth of massive/stellar mass seed BHs at high-z universe is believed to be one of the possible solutions to grow the observed supermassive black holes (SMBHs) at z~6. We study the long-term evolution of the global structure of axisymmetric accretion flows onto a black hole (BH) at rates substantially higher than the Eddington value, performing two-dimensional radiation hydrodynamical (RHD) simulations. In the high-accretion optically thick limit, where radiation energy is efficiently trapped within the inflow, the accretion flow becomes adiabatic and comprises of turbulent gas in the equatorial region and strong bipolar outflows. As a result, the mass inflow rate decreases towards the center as a power law relation and only a small fraction of inflow gas feeds the nuclear BH. Energy transport via radiative diffusion accelerates the outflow near the poles in the inner region but does not affect the overall properties of accretion flow. Based on our simulation results, we provide a mechanical feedback model for super-Eddington accreting BHs, which can be applied to large-scale simulations that hardly resolve galactic nuclei. We applied the feedback model to the assembly of first massive BHs observed in high-redshift quasars and find that the existence of strong outflows can suppress the BH growth, while moderate outflows can coordinate the early BH-galaxy co-evolution.

X-raying extreme nuclear transients

Type: Invited Talk

Author: Erin Kara

In recent years, time-domain surveys have revealed new, transient accretion phenomena that defy all predictions. We witness stars getting ripped apart by black holes (known as Tidal Disruption Events) and Active Galactic Nuclei that suddenly accrete material at rates orders of magnitude faster than disk theory predicts. A key to explaining much of this staggering behavior is to probe close to the black hole, as seen in X- rays. In this talk, I will discuss some recent results on TDEs, changing-look AGN and a newly discovered class of transients, Quasi Periodic Eruptions, all of which are furthering our understanding of the extreme accretion environments around supermassive black holes.

Detection of high frequency quasi-periodic oscillation during the reflare of MAXI J1348-630

Type: Poster

Primary Author: Raj Kumar

Co-authors: Nilay Bhatt, subir Bhattacharyya

In this talk, I will discuss the detection of high frequency quasi-periodic oscillation (QPO) in the black hole x-ray binary MAXI J1348-630 in its hard spectral state. MAXI J1348-630 went through a reflare during MJD 58634 to MJD 58674 after a 104 days long outburst which began on MJD 58509. During the reflare the binary system evolved through a series of hard states of varying luminosity. We detected a high frequency QPO at 98.3 Hz with a significance of 3.7σ in one of the NICER observations during its evolution. It was argued that the QPO frequency might be related to the Keplerian frequency of the accretion flow at the inner radius around a Kerr black hole.

Simulating Bondi-Like Accretion Flow Around Black Holes

Type: Contributed Talk

Primary Authors: Tom Kwan

Co-authors: Jane Dai, Alexander Tchekhovskoy

While black hole accretion flow simulations usually start from gas disks with relatively large an- gular momenta, many important black hole astrophysical systems are believed to be fed by gas with low angular momenta, such as tidal disruption events, long gamma-ray bursts and wind-fed high mass X-ray binaries. We carry out 3D general relativistic magnetohydrodynamic (GRMHD) simulations of accretion flows with zero or very low specific angular momenta around rapidly spin- ning black holes. We thread the flows with large amounts of large-scale ordered magnetic fields. The results show that such accretion flow needs to initially have a specific angular momentum above a certain threshold to eventually reach and robustly sustain the magnetically arrested disk (MAD) state. If the flow can reach the MAD state, it can launch very powerful jets. Furthermore, we realize that even when the accretion flow has initial specific angular momentum below the threshold, it can still launch episodic jets with an average energy efficiency of $\sim$ 10%. However, the accretion flow has non-typical and interesting behaviours in this situation. Our results give an insight into the behaviour of the accretion flow and the production of relativistic jets in various astrophysical systems in which the accretion flows likely have low specific angular momenta.

Jetted Tidal disruption events: black hole spin, jet components and circumneuclear medium

Type: Contributed Talk

Author: Weihua Lei

Co-author: Chang Zhou

A star will be destroyed by tidal forces when it passes close enough by a supermassive black hole (SMBH). These events known as TDEs are expected to produce luminous flare emission in the UV to X-ray band. The observations of Sw J1644+57, in particular, suggest that at least some TDEs can launch an on-axis relativistic jet. A common speculation is that these rare events are related to rapidly spinning BHs, and the jet is powered by the Blandford-Znajek mechanism. Until now, four on-axis jetted TDEs were detected, i.e., Sw J1644+57, Sw J2058+05, Sw J1112.2-8238 and recently AT2022cmc. The rich obervation data (e.g., X-ray QPOs, radio data etc.) enable us to explore the properties of BH, jet and circumneuclear medium (CNM). In this talk, I will present our constraints on BH spin, jet components and CNM profile.

Tidal Disruption Events in XMM-Newton slew survey and some preliminary results of LEIA

Type: Contributed Talk

Primary Author: Dongyue Li

Co-authors: Richard Saxton, Rhaana Starling, Weimin Yuan

Tidal disruption event (TDE), where a star is ripped apart by the strong tidal forces of a supermassive black hole (SMBH), creates an impulse of accretion, resulting in bright flare that decays in time-scales of months to years, thus provides a unique tool to detect dormant black holes and investigate the accretion process around SMBH. We have built a sample of highly variable X-ray sources, including several TDE candidates, from XMM-Newton slew survey (XMMSL) by comparing their fluxes with that measured in RASS. Here we will talk about the highly variable X-ray sources and a detailed multiwavelength analysis of one TDE which shows brightening in both optical/UV and X-ray band. Besides, XMMSL has similar energy coverage and sensitivity in soft X-ray as Einstein Probe (EP), and the variable content of XMMSL can be used as a reference for the long-term variable and transient sources that EP will detect. An experimental module of the EP-WXT telescope, namely LEIA, was launched on July 27, 2022 and has started its regular scientific surveys since Nov. 2022. In this talk, we will also briefly introduce some preliminary results of LEIA.

The Transient Slim Disk of the Changing-look Active Galactic Nucleus 1ES 1927+654

Type: Contributed Talk

Primary Author: Ruancun Li

Co-authors: Luis Ho, Claudio Ricci, Kara Erin, Benny Trakhtenbrot

In changing-look AGNs, the optical-to-X-ray continuum flux typically increases significantly as broad emission lines appear. The changing-look AGN 1ES 1927+654, hosting already a highly accreting black hole, displays peculiar X-ray properties after its optical changing-look event in early 2018. We carried out a follow-up campaign to probe its extreme accretion physics, using 34 optical spectra, 800 NICER and 14 Swift/XRT observations, as well as 7 simultaneous XMM-Newton/NuSTAR exposures. Detailed spectral energy distribution analysis suggests that the black hole was accreting super-critically, with $t^{-5/3}$ declining mass accretion rate. The bolometric luminosity was logarithmically dependent on the mass accretion rate, suggesting the existence of a slim disk. After $0.55 M_{\odot}$ of material was consumed, the evolution of the radiation efficiency and disk temperature suggests that the accretion flow finally returned to a thin disk. The mass budget yields the radius of the most bound orbit, which is consistent with the broad-line region orbit, favoring a tidal disruption event as the origin of the outburst. During the transient slim disk phase, the X-ray corona tightly correlated with the properties of the inner accretion flow, suggesting that the corona plasma originated from the disk itself. Additionally, the UV-X-ray spectral index and bolometric correction follow a completely different branch during the slim disk phase. We model the X-ray variability with a Gaussian process, finding that the correlation timescale is tightly correlated with disk properties. This study provides several important insights into the physical properties of slim disks and the AGN unified model.

Can Transients Comprising Stellar Population in Galaxy Clusters Constrain Fraction of PBHs in Dark Matter?

Type: Poster

Primary Author:Sung Kei Li

Co-authors: Amruth Alfred, Jose Maria Diego, Patrick Kelly, Jeremy Lim

Primordial Black Holes (PBHs), proposed to be formed during gravitational collapses of matter in the very beginning of the universe, are one of the many candidates that have been proposed to be a constituent of Dark Matter (DM). They are especially interesting in the fact that they do not need to invoke an unknown particle, and therefore new physics. Postulated to span a wide range of masses (10^{17}–10^{23} g and 10–10^2 $M_\odot$), various efforts have been proposed (or carried out) to place limits on the abundance and mass of PBHs. For example, monitoring of lightcurves of extragalactic transients featuring single stars being microlensed is expected to be capable of constraining the fraction of $30M_\odot$ PBHs down to less than 10\% of the total DM fraction.

Here, we consider for the first time constraints imposed on PBHs by transients featuring persistent sources seen towards galaxy clusters. Assuming that these transients are induced by stellar (and PBH) microlensing of star-forming regions in a background galaxy that is themselves lensed by the galaxy cluster, we investigate how the total fluxes can vary over observations according to our simulations. In particular, we select a PBH mass of 30 $M_\odot$ as a showcase where we demonstrate that under low magnification and low stellar surface mass density, considering 1.5\% of the total DM mass as PBHs will increase the flux variability of such stellar populations and therefore the probability of observing a detectable transient event appreciably. Given the fact that we have an ample amount of such kind of persistent stellar populations in galaxy clusters (for example, the Dragon Arc in Abell 370), we suggest that with long-term monitoring of their flux variability, one can compare the detection rate with the estimated transient detection rate using our methodology of simulation as an alternate method in constraining the abundance of PBHs in DM. With the current data from the Flashlights survey, we are able to constrain the fraction of PBHs in DM down to <5% as a first-order approximation. With more observational data coming in the future, it is expected we can put tighter constraints on the ≃$30M_\odot$ PBH abundance in DM.

Pathway to high-z SMBHs: seed formation and growth in the statistical perspective

Type: Contributed Talk

Primary Author: Wenxiu Li

Co-authors: Kohei Inayoshi, Masafusa Onoue, Daisuke Toyouchi, Yu Qiu

The early evolution of the black hole mass function (BHMF) and quasar luminosity function (QLF) encodes key information on the physics determining the radiative and accretion processes of black holes (BHs) growing in high-redshift galaxies. Starting from the formation of seed BHs as their parent halos evolve, we study primordial gas collapse in the biased quasar host halos, computing gas chemical and thermal evolution, environmental UV radiation, and merger heating following halo merger trees. As gas collapses, the accretion rate onto a newly-born protostar ranges between 0.003-5 M_{sun}/yr, leading to a top-heavy seed BH mass distribution ranging from several hundred to above 10^5 solar mass. We then construct a theoretical BH growth model via multiple accretion bursts constrained by z~6 QLF and BHMF observations. In a statistical way, we predict that in every active episode, BHs grow with an Eddington ratio distribution function following the Schechter shape. Imposing a luminosity limit of quasar surveys, we find that the observed Eddington-ratio distribution function is skewed to a log-normal shape, preferentially selecting more active quasars. The predicted redshift evolution of the QLF and BHMF suggests a rapid decay of their number and mass density in a cosmic volume toward z>6. JWST and future devices will push BH observations to mass ranges lower than typical high-redshift quasars, and help explore the growth history of BHs in the early universe and the establishment of BH-galaxy coevolution.

The generalized self-similar solution of ADAF, SLE, slim disk and standard disk

Type: Poster

Author: Mingjun Liu

Accretion is the energy source for many high-energy astrophysical phenomena. Since 1970s four basic solutions describing the accretion processes have been established with specific assumptions, i.e., the standard thin disk (SSD), the Shapiro-Lightman-Eardley (SLE) solution, the slim disk and the advection-dominated accretion flow (ADAF). We present a generalized self-similar solution based on the axisymmetric height-average equations of ADAF, aiming to unify the four solutions. In addition to the advection, the radiation pressure and photon trapping are also included self-consistently. Our generalized solution can reproduce the ADAF, SLE, SSD and slim disk branches in a wide range of accretion rate from sub- to super-Eddington accretion. In particularly, it displays the regimes of accretion rate for the four solutions, the distinct advection fraction of accretion energy, the different temperatures and the thickness of the four accretion flow. A S-curve in $\dot{m}$-Σ plane is also reproduced, representing the SSD branch, the radiation pressure-dominant branch and the slim disk branch. A surprising solution occurs in the innermost region where the radiation pressure becomes dominant. This solution is characterized by high temperature (heated by a very small fraction of advection energy) and effectively optically thin, where the classic SSD solution is no longer self-consistent.

Connecting the branches to the roots: confronting long-standing questions about jet physics in the global VLBI/EHT era

Type: Invited Talk

Author: Sera Markoff

Co-authors: K. Chatterjee, D. Kantzas, M. LIska, M. Lucchini, G. Musoke, B. Ripperda, L.S. Salas, D. Yoon, Z. Younsi

Black hole jets are a challenging puzzle, as they require insights over a range of scales impossible to capture with any one method. Somehow effects playing out at galactic scales are rooted in microphysical processes occurring just outside an event horizon, that somehow also determine the formation of special regions where particle acceleration preferentially occurs. Thanks to global very long baseline interferometry (VLBI) projects like the Event Horizon Telescope (EHT) and Global mm-VLBI Array (GMVA), we are finally gaining access to regions we could only dream of directly imaging decades ago when many key questions were formulated about jets. But high-precision imaging is not enough to break the many degeneracies inherent in the models. In this talk I will review recent progress where precision VLBI imaging, in combination with new multi-wavelength constraints and modelling techniques, is helping to address a range of questions regarding accretion physics and geometry, jet launching, and the origin of

high-energy flares. I will also discuss the prospects as we move into an era of dynamical imaging as well as more sensitive high-energy facilities such as the Cherenkov Telescope Array.

Relativistic Jet Simulations and Modeling on Horizon Scale

Type: Contributed Talk

Author: Yosuke Mizuno

Relativistic jets are launched in the vicinity of the central black holes and emit powerful radiation across the electromagnetic spectrum. According to our current understanding, relativistic jets are launched by directly tapping the rotational energy of spinning black holes via the so-called Blandford-Znajek process. In addition to the spin of the black hole, numerical simulations showed the amount of accreted magnetized flux has a major impact on the formation of relativistic jets. We have investigated the radiative signatures of self-consistently launched relativistic jets using 3D general relativistic magneto-hydrodynamical simulations and general relativistic radiative transfer calculations in horizon scale to the connection with large-scale structure. We discuss our findings and comparison with observations.

Investigating jet physics via the joint modelling of Event Horizon Telescope images and multi-wavelength observations

Type: Contributed Talk

Author: Wanga Mulaudzi

Co-authors: S.B. Markoff, K. Chatterjee, Z. Younsi, L.S. Salas

A key characteristic of some active galactic nuclei (AGN), such as radio galaxies, is that they possess powerful jets that can extend through or beyond their host galaxy. However, the exact mechanisms of their launch and their internal properties are still not well understood. In this talk, I will focus on Event Horizon Telescope (EHT) and multi-wavelength images and spectral observations of our neighbouring AGN, M87. In particular, I investigate what processes are responsible for the particle acceleration physics by studying the effect of the choice of electron distribution function (eDF) on the subsequent images and spectra our model produces. Using general relativistic ray tracing for each eDF choice to postprocess general relativistic magnetohydrodynamic (GRMHD) simulation snapshots I produce multi-frequency synchrotron images and extract spectra from the radio through X-rays. There is a degeneracy in the simulation process because we do not calculate the eDFs from first principles but rather explore preset parameterised eDFs based on particle-in-cell (PIC) simulations that consist of more accurate plasma physics simulations. In this talk, I will present and discuss initial comparisons between simulations of M87 and 2017 multi-wavelength data published by the EHT Collaboration Multi-wavelength Science Working Group. I will also discuss the next steps, such as the development of an automated optimisation pipeline that will be used in future EHT and multi-wavelength studies.

New Results on Astrophysical Black Holes from eROSITA

Type: Invited Talk

Author: Kirpal Nandra on behalf of the eROSITA team

The eROSITA X-ray telescope was launched in July 2019 aboard the Spektrum-RG satellite. After a short performance verification phase, it has subsequently performed an X-ray all-sky survey of unprecedented depth. Accreting supermassive black holes in active galactic nuclei (AGN) constitute the most numerous class of sources detected by eROSITA. The high sensitivity and large field of view of the instrument provide large sample sizes enabling robust statistical studies of the X-ray AGN population, as well as the first significant samples of the rarest objects, e.g. those at high redshift. The distinctive temporal sampling pattern provided by the survey also provides unique information about the variability of the X-ray sky. In this presentation, early AGN results from eROSITA will be reviewed. These have confirmed its potential to yield new insights into black hole demographics and accretion physics, and yielded a number of surprising new discoveries.

Evolution of wandering intermediate-mass black holes in high-z galaxies with 3D radiation hydrodynamics simulations

Type: Contributed Talk

Primary Author: Erika Ogata

Co-authors: Ken Ohsuga, Hajime Fukushima, Hidenobu Yajima

We have, for the first time, successfully performed three-dimensional radiative hydrodynamics simulations of the gas accretion onto intermediate-mass (IMBHs) black holes wandering in the high-z galaxies. Here the sublimation of the dust grain caused by

the radiation from the accretion disks around IMBHs is taken into consideration. We found that the accretion rate and acceleration are ~7×10^{-6} $M_\odot$ yr^{-1} and ~10^{-8} cm s^{-2} in environments with relatively high density($\geq10^4$ cm^{-3}) and low metallicity ($0.1Z_\odot$). These results suggest that IMBHs keep floating in the galactic disk with insignificant mass growth. For extremely high density ($\geq10^6$ cm^{-3}), as suggested by recent observations from the James Webb Space Telescope, the accretion rate and acceleration rise significantly. This indicates that IMBHs are ejected from the galactic disk due to an increase in mass and velocity.

Radiation MHD simulations of super-/near-Eddington accretion flows and outflows

Type: Invited Talk

Author: Ken Ohsuga

By performing the radiation-MHD simulations, we reveal the global inflow and outflow structures around black holes. The optically and geometrically thick disks supported by the radiation pressure form, and the powerful outflows are driven by the radiation force for electron scattering in the super-Eddington phase. A part of the outflows fragments into numerous gas clouds, and the outflow generated near the trapping radius falls to the disk surface. It is also found that, for the case of the rotating black holes, the energy conversion efficiency increases, and the precession motion of the disk occurs. In the near-Eddington case, the radiation force for spectral lines is responsible for the disk winds, which is thought to be the origin of the ultrafast outflows.

Sgr A* spin and mass estimates through the detection of an extremely large mass-ratio inspiral

Type: Contributed Talk

Primary Author: Alejandro Torres Orjuela

Co-authors: Yiren Lin, Veronica Vazquez-Aceves

Estimating the spin of SgrA* is one of the current challenges we face in understanding the center of our Galaxy. In the present work, we show that detecting the gravitational waves (GWs) emitted by a brown dwarf inspiraling around SgrA* will allow us to measure the mass and the spin of SgrA* with unprecedented accuracy. Such systems are known as extremely large mass-ratio inspirals (XMRIs) and are expected to be abundant and loud sources in our galactic center. We consider XMRIs with a fixed orbital inclination and two scenarios for SgrA*'s spin (s): A highly spinning scenario where s=0.9 and a low spinning scenario where s=0.1. For both cases, we obtain the number of circular and eccentric XMRIs expected to be detected by space-borne GW detectors like LISA and TianQin. We later perform a Fisher matrix analysis to show that by detecting a single XMRI the mass of SgrA* can be determined with an accuracy ranging from 0.017 and 0.06 solar masses, while the spin can be measured with an accuracy between 1.7×10^{-7} and 7.5×10^{-4}.

The susceptible GW sources in the AGN accretion disk

Type: Contributed Talk

Primary Primary Author: Peng Peng

Co-authors: Xian Chen

Extreme-mass-ratio inspirals (EMRIs) and intermediate-mass-ratio inspirals (IMRIs) are important gravitational-wave (GW) sources for the Laser Interferometer Space Antenna (LISA). So far, their formation and evolution are considered to be independent, but recent theories suggest that stellar-mass black holes (sBHs) and intermediate-mass black hole (IMBHs) can coexist in the accretion disk of an active galactic nucleus (AGN), which indicates that EMRIs and IMRIs may form in the same place. In this presentation, I will talk about our study on the interaction between a gap-opening IMBH in an AGN disk and the sBHs surrounding it, motivated by the fact that a gas giant migrating in a protoplanetary disk could trap planetesimals close to its orbit. We analyze the torques imposed on the sBHs by the disk as well as by the IMBH, and show that the sBHs can be trapped by the IMBH if they are inside the orbit of the IMBH. We implement the torques in our numerical simulations to study the migration of an outer IMBH and an inner sBH, both embedded in an AGN disk. We find that their migration is synchronized until they reach a distance of about ten Schwarzschild radii from the central supermassive black hole, where the pair break up due to strong GW radiation. This result indicates that LISA may detect an EMRI and an IMRI within several years from the same AGN. Such a GW source will bring rich information about the formation and evolution of sBHs and IMBHs in AGNs.

Cold Gas in Outflow: Evidence for Delayed Positive AGN Feedback

Type: Poster

Primary Author: Yu Qiu

Multiphase outflows driven by active galactic nuclei (AGN) have a profound impact on the evolution of their host galaxies. The effects of AGN feedback are especially prominent in the brightest cluster galaxies (BCGs) of cool-core clusters, where there is a concentration of gas in all phases, ranging from cold molecular gas to hot, > 10^7 K ionized plasma. In this talk I describe recent simulation efforts to understand the formation and evolution of the 10-kpc-scale Hα-emitting filaments driven by AGN activities. Combined with observed star formation regions co-spatial with the filaments, this feedback mechanism can directly contribute to the growth of the central galaxy, albeit delayed by the characteristic radiative cooling timescale, ~10 Myr, of the outflowing plasma.

Can two-temperature treatments in GRMHD simulations reduce the predicted variability compared to historical observations of Sgr A*?

Type: Contributed Talk

Author: Leon S. Salas

Co-authors: S.B. Markoff, K. Chatterjee, D. Yoon, G. Musoke, W. Mulaudzi, R. Leichtnam

Recent direct imaging by the Event Horizon Telescope Collaboration (EHTC) has confirmed the existence of an event horizon in Sagittarius A* (Sgr A*), the supermassive black hole at the center of the Milky Way. To model and interpret these data, the EHTC compares them to a library of fiducial models based general relativistic magnetohydrodynamic (GRMHD) simulations. One significant source of inaccuracy stems from the fact that the evolution equations model only a single-particle fluid with temperature associated with the proton temperature, and thus do not account for the electrons self-consistently. Instead, as an approximation, the EHTC uses a pre-determined prescription of the temperature ratio between electrons and protons typically based on the local magnetisation of the plasma. This approximation strongly affects the predicted emission, since the radiative transfer depends on the electron temperature assuming a thermal distribution function. One way these models can be tested is via variability of light curves at 230 GHz. Observations of Sgr A* spanning decades give very strong constraints on the variability, and so far all of the strongly magnetized models used by the EHTC show too much variability comparatively. Moreover, none of the models successfully pass all the variability and multiwavelength constraints together.

The temperature ratio between protons and electrons depends on a balance between microphysical dissipation not captured in ideal fluid simulations, radiative cooling, and fluid transport. Therefore, we investigate the effects of two-temperature thermodynamics of a magnetically arrested disk around Sgr A*, where the temperatures of both species are evolved more self-consistently following a method by Ressler et al. (2015) and Sadowsky el al. (2017). We include Coulomb coupling, heating of non-thermal electrons via an assumed magnetic reconnection mechanism (Rowan et al. 2017) and radiative cooling. Simulations incorporating radiative cooling already show differences in the dynamical and geometrical properties of the accretion flow compared to fiducial models, but the inclusion of heating in addition and two-temperature thermodynamics has not been studied, particularly at higher resolution. These effects also depend strongly on accretion rate which is another unknown variable. In this talk I will present our recent study of the impact of these effects on the predicted light curve and morphology of the accretion flow close to the black hole, and compare our results to the fiducial models used by the EHTC in its 2022 study of the first campaign on Sgr A*.

Different Angles on Accreting Supermassive Black Holes

Type: Invited Talk

Author: Prajval Shastri

In this talk I will review the phenomenology of accreting supermassive black holes and their jets. The understanding that has emerged from their systematics at multiple frequencies, combined with the results from computational simulations and connections with properties of their host galaxies and their evolution will be discussed.

Possibility of black hole spin estimation with time-variable “crescent-shaped” shadow in M87

Type: Contributed Talk

Primary Author: Mikiya Takahashi

Co-authors:Tomohisa Kawashima, Ken Ohsuga

It is a great challenge to constrain the spin magnitude of the black holes (BHs). We have calculate a radio image of M87 in a flaring state using a part of time-dependent general relativistic radiative transfer code: CARTOON (Takahashi et al. 2022), and found that a time variable "crescent-shaped" shadow appears and its width depends on the BH spin magnitude. Following our previous work (Kawashima et al. 2019, here after TK19), we assume that the accretion flow is optically thick against the synchrotron self-absorption (SSA) in a flaring state, where the mass accretion rate will be relatively higher than that observed by the Event Horizon Telescope (EHT) in 2017. As is known that M87 shows a time variability over a few days, we have developed a steady model of TK19 by incorporating a time variability of accretion flow with a time scale of a few days, as observed in M87. In the light curves of the radio images, we have also found a time-delayed variability of the photon ring component, which would be also an important feature to probe the BH spin. The time variability of the "crescent-shaped" shadow may depends on the BH spin magnitude. In this talk, we discuss about a behavior of the “crescent-shaped” shadow in a toy model and future issues.

Dynamical Unification of Tidal Disruption Events

Type: Contributed Talk

Author: Lars Thomsen

Co-authors: Tom Kwan, Jane Dai, Samantha Wu, Nathaniel Roth, Enrico Ramirez-Ruiz

A Tidal Disruption Event (TDE) happens when a black hole devours an unlucky star which gets too close. The first few detected events emit primarily in the X-ray, which is consistent with the early predictions. However, up to now ~100 TDEs have been detected with the help of various transient surveys, and two main classes of TDEs exist distinguished by the main emission type at peak: X-ray-dominated and optical-dominated. It is also recently discovered that many optical TDEs have X-ray brightening at late time, meaning that their X-ray emissions steadily increase while the optical emissions decline for 10s-100s days after peak.

In this talk, I discuss how we can link these distinct observed classes and evolution of TDEs to a dependence on the viewing angle upon and accretion rate of a super-Eddington disk formed in TDEs. More specifically, I employ *Sedona*, a Monte Carlo radiative transfer code, to post process on super-Eddington accretion flow obtained through 3D general relativistic radiation magnetohydrodynamics simulations and obtain reliable spectra. Our new results confirm the unified model previously proposed by Dai et al. (2018), suggesting that the observed emission properties depend largely on the observer's viewing angle. Furthermore, we show that as the accretion level declines with the fallback rate, the super-Eddington funnel opens up and more X-rays to leak out along intermediate viewing angles, providing a natural explanation for the diversity of emission properties observed in TDEs and their evolution.

A Black Hole Closeup: Enhancing Black Hole Science with the ngEHT and Space

Type: Invited Talk

Author: Paul Tiede

After over a century since their initial mathematical description, black holes and their surroundings remain poorly understood. In April 2019, the Event Horizon Telescope released the first image of a black hole, bringing the nature of physics at horizon scales into focus. This talk will detail how additional telescopes will enhance fainter features of black holes, their surrounding environment, and sharpen our understanding of gravitational physics near the event horizon. Adding additional ground telescopes will allow the next-generation Event Horizon Telescope to see closer to the horizon, measure its properties, and create black hole cinema. These movies will enable direct studies of the dynamics of accretion and the conditions of jets near the horizon. Furthermore, the addition of a space telescope will further focus on the role of gravity, creating the highest-resolution images ever produced and enabling new tests of general relativity.

Energy outflow efficiency of the supercritical accretion disks around Kerr-black holes by General relativistic radiation-MHD simulations from weak to strong magnetic field state

Type: Poster

Primary Author: Aoto Utsumi

Co-authors: Ken Ohsuga, Hiroyuki Takahashi, Yuta Asahina

By performing two-dimensional general relativistic radiation magnetohydrodynamics (GRRMHD) simulations with various spin parameters, $a*$, we investigate the supercritical disks in the standard and normal evolution (SANE) and magnetically arrested disk (MAD) states. As a result, it is revealed that the energy outflow efficiency increases with $|a^*|$ in the SANE state. For example, it is 5% for $a^* = 0.7$, which is much larger than 0.3% for $a^* = 0$, when the disk is in the SANE state and the mass accretion rate is ~$100L_{\rm Edd}/c^2$ ($L_{\rm Edd}$ is Eddington luminosity). Such $|a^*|$-dependence appears if the disk is in the MAD state. In addition, we find that energy outflow efficiency is about ten times larger in the MAD state than in the SANE state. That is, the mass accretion rate to explain the energy of luminous compact objects such as AGNs and ULXs is lowest for rapidly rotating black holes with disks in the MAD state and highest for non-rotating black holes with disks in the SANE state. In both cases, although the disk releases the energy mainly by the radiation in the case of the non-rotating black holes, the energy is ejected through the Poynting flux when the black holes rapidly rotate. Therefore, the objects, of which the central black holes rapidly rotate, are identified as powerful sources with a large ratio of kinetic power to photon luminosity. Using this argument, the spin parameter of the black hole of ULX, IC 342 X-1, is expected to be $|a^*|>0.5$.

Gravitational radiation from close binaries of supermassive black holes and massive stars

Type: Poster

Primary Authors: Alexandr Volvach

Co-authors: Larisa Volvach, Mikhail Larionov

Supermassive black holes (SMBHs) at the centers of galaxies can be very powerful objects, emitting in all ranges of the electromagnetic spectrum, including the important range of gravitational waves (GW). However, there are practically no active galactic nuclei (AGNs) with close binary systems from SMBHs with precisely defined kinematic and dynamic characteristics of the components necessary to determine the parameters of GW emission. This can be attributed both to the insufficiency of multifrequency data obtained on the basis of long-term monitoring and the lack of a clear methodology for determining the main SMBH parameters. The last statement involves the creation of a special mathematical apparatus for this purpose.

The kinematic and dynamic characteristics of the components require knowledge of the models of black hole orbits, their masses, and the dynamic losses of the system. To do this, it is necessary to investigate, among other things, the physical conditions in the central regions of AGN. Therefore, multi-frequency monitoring of flux densities on individual antennas can be of paramount importance for finding the required SMBH parameters.

We propose a new method for calculating the parameters of the orbits of double supermassive black holes using only multi-frequency monitoring data in the radio band. The relevance also applies to close binary (multiple) stellar systems in the Galaxy, which are also capable of emitting GW. In connection with flare phenomena in the framework of the model of close binary massive star systems (CMSSs), we consider the possibility of detecting gravitational waves from CMSSs in the regions of active star formation. The possibility of detecting GWs from CMSSs was considered.

(This work was funded by the RSF, project number 23-22-10032.)

Compact objects around SMBHs: QPEs, FRBs and EMRIs

Type: Contributed Talk

Author: Fayin Wang

In this talk, the GW and EM radiation from a compact object orbiting an SMBH are discussed. First, I will present a new formation channel of EMRIs with tidal disruption flares as EM counterparts. In this scenario, flares can be produced from the tidal stripping of the helium (He) envelope of a massive star by an SMBH. The remaining compact core of the massive star then evolves into an EMRI. Second, Quasi-periodic eruptions (QPEs), a new kind of X-ray burst with a recurrence time of several hours, have been detected from SMBHs in galactic nuclei. QPEs can be generated from the Roche lobe overflows at each periapsis passage of an evolved star orbiting a SMBH. Third, the large rotation measures of some repeating FRBs indicate they are produced by neutron stars around SMBHs. In these above scenarios, low-frequency gravitational-wave EMRIs will be generated. The implication of joint detection of EMRIs and EM signals are discussed.

Signatures of binary supermassive black holes in AGNs from reverberation mapping and GRAVITY/interferometer

Type: Contributed Talk

Author: Jian-Min Wang

Binary supermassive black holes located in galactic nuclei produce gravitational waves with frequencies in the nano-Hz range, but their detection through observations remains elusive. Reverberation mapping (RM) of active galactic nuclei (AGNs) and the VLT interferometer are powerful tools that can reveal temporal and spatial resolution signatures of binary black holes. Here we present key signatures obtained through RM and GRAVITY observations.

Particle acceleration in AGN jets

Type: Contributed Talk

Author: Jieshuang Wang

Jets of active galactic nuclei are observed from less than parsec scale to mega-parsec scale. They are powerful particle accelerators shining across the electromagnetic spectrum. In this talk, (1) I'll mainly present our analytical and numerical works on shear acceleration. Recent observations indicate a synchrotron origin of X-ray emission in kpc-scale, which requires in-situ acceleration of electrons up to near PeV energies. We found an exact solution of the steady-state Fokker-Planck equation for shear acceleration. This produces a power-law spectrum with an exponential-like cut-off for particles, which can naturally explain the multi-wavelength observations of the kpc-scale jets, such as Centaurus A and 3C 273. Our relativistic MHD simulations and test-particle simulations validate the assumptions of our analytical theory and show that protons can be accelerated to the Hillas limit via shear acceleration. (2) I'll also briefly discuss the particle acceleration mechanisms in sub-pc scale jets, especially for the limb-brightened structures.

Black holes regulate cold gas accretion in massive galaxies

Type: Contributed Talk

Author: Tao Wang

Nearly every massive galaxy contains a supermassive black hole (BH) in their centers. For decades, both theories and numerical simulations suggest a central role of BHs in regulating the growth of galaxies. In particular, BH feedback through heating or blowing up the interstellar medium (ISM) serves as the foundation for current models of massive galaxy formation. However, direct evidence for such an impact on the galaxy-wide ISM from BHs has only been found for some most extreme objects. For general galaxy populations, it remains unclear on how BHs affect the ISM. Here based on a large sample of nearby galaxies with measurements of both BH mass and atomic hydrogen, the major component of cold ISM, we reveal that the atomic hydrogen content ($f_{\rm HI}$=$M_{\rm HI}/M_\star$) is tightly and inversely correlated with BH masses with $f_{\rm HI}\propto M^{-\alpha}{}_{\rm BH}$($\alpha$~0.6), which is valid across five orders of magnitude in BH masses. Once this correlation is accounted for, $f_{\rm HI}$ loses dependence on other galactic parameters, indicating that BHs masses serve as the primary driver of $f_{\rm HI}$. This result provides critical evidence on how the accumulated energy from BH accretion affects the surrounding ISM, which marks an important step forward in our understanding on the central role of BHs in regulating the growth and quenching of galaxies.

Density profile of the ambient circumnuclear medium in Seyfert 1 radio-quiet galaxies

Type: Contributed Talk

Primary Author: Yijun Wang

Co-authors: Zhicheng He, Junjie Mao, Jelle Kaastra, Yongquan Xue, Missagh Mehdipour

The shape of the ambient circumnuclear medium (ACM) density profile can probe the history of accretion onto the central supermassive black holes in galaxies and circumnuclear environment. However, due to the limitations of instrument resolution, the density profile of the ACM for most galaxies remain largely unknown. Here we propose a novel method to measure the ACM density profile of active galactic nuclei (AGNs) by the equilibrium between the radiation pressure on the warm absorbers (WAs, a type of AGN outflow) and the drag pressure from the ACM. We study the correlation between the outflow velocity and ionization parameter of WAs in each of the five Seyfert 1 radio-quiet galaxies, inferring that the index of ACM density profile is between -1.7 and -2.15 from 0.01 to 1 parsec scale. Our results indicate that the ACM density profile in these five Seyfert 1 radio-quiet galaxies is consistent with the prediction by the standard thin-disk model, and steeper than the prediction by the spherically symmetric Bondi accretion model and simulated results of the host accretion model.

Accretion flows in the wind-fed black holes

Type: Poster

Primary Author: Yilong Wang

The hot wind captured by the black hole can naturally form an advection dominated accretion flow (ADAF), which, as it flows toward the black hole, partially condensates into a cold disk as a consequence of efficient radiative cooling at small distances, and then accretes to the black hole via a disk-corona configuration. We present our detailed study of such accretion flows possibly exist in high-mass black hole X-ray binaries or active galactic nuclei. We find that the hot accretion flow remains as an ADAF at all

distances at low accretion rates, however, it changes to a corona lying above a weak thin disk in the innermost region when the accretion rate supplied by the wind exceeds a critical value, $\dot{m}$≃0.02. The overall spectra are typical hard-state spectra, hardening with the increase of accretion rate until an upper limit of 0.05 (corresponds to 0.03 Eddington luminosity). We demonstrate that such accretion flows reproduce the observed spectrum of Cygnus X-1 in the hard state. The presence of a weak disk around ISCO offers an interpretation to the broad Fe Kα line in the hard state. A disk-dominated soft state is anticipated at high accretion rates in the frame of such a condensation scenario.

Multi-Messenger Constraint on the Hubble Constant with Tidal Disruption Events

Type: Poster

Author: Thomas Hong Tsun Wong

Tidal disruption events (TDEs), apart from producing luminous electromagnetic (EM) flares, can generate potentially detectable gravitational wave (GW) burst signals by future space-borne GW detectors. We propose the first methodology to constrain the Hubble constant H_0 with TDEs by incorporating the EM-observable parameters (e.g., stellar mass, black hole (BH) mass, and spin) into fitting the observed TDE GW burst waveforms. We argue that an accurate knowledge of the BH spin could help constrain the orbital inclination angle, hence alleviating the well-known distance-inclination degeneracy in waveform fitting. For individual TDEs, the precise redshift measurement of the host galaxies along with the luminosity distance D_L derived from the combination of EM and GW signals would give a self-contained measurement of H_0 via Hubble's law, completely independent of any specific cosmological models. As the simultaneous EM-GW detections proliferate, TDE demographic analysis could lead to an accurate measurement in addition to the standard siren approach.

Black hole mass and the reverberation size-luminosity relation based on the 6-year Seoul National University Monitoring Project (SAMP)

Type: Contributed Talk

Primary Author: Jong-Hak Woo

Co-authors: SAMP Collaboration, Hojin Cho, Shu Wang

Black hole mass is a key parameter for understanding black hole growth and AGN physics. The method of determining black hole has been rapidly evolved over the last 20 years. We will present the latest results of reverberation mapping (RM) studies based on the 6 year SNU monitoring project, using a sample of 32 AGNs with relatively high luminosity (*L*_5100>10^44erg/s). With hundreds of nights of regularly sampled spectroscopic/photometric observations, we successfully obtain reliable H beta lags and BH masses for 24 objects, finding that the BLR sizes of these objects are smaller than the expectation from the previous size-luminosity relation. By applying a uniform lag analysis to available H beta RM light curves from the literature, we remeasured the H beta lag of the most reliable ~100 AGNs, redefining the size--luminosity relation with a slope of 0.41±0.22 and an intrinsic scatter of 0.192 dex. For ~20 AGNs, we will present the velocity resolved lag measurements and discuss the implication of these results on the BLR properties. We will also present the H alpha size-luminosity relation and discuss new constraints on finding intermediate-mass black holes. Finally we will review the uncertainty of black hole masses based on the size-luminosity relation and single-epoch method.

Apparently ultra-long period radio sources from self-lensed pulsar-black hole binaries

Type: Poster

Primary Author: Xinxu Xiao

Co-authors:Rong-Feng Shen

Pulsar-black hole (BH) binary systems, which have not been found yet, are unique celestial laboratories for testing relativistic theories of gravity and understanding the formation of gravitational wave sources. We study the self gravitational lensing effect in a Pulsar-BH system. Because this effect from the BH magnifies the pulsar signal once per orbital period, we find that it may generate apparently ultra-long period (~ hours) radio signal when the intrinsic pulsar signal is weak or the system is at large distances. When the lensed source is a millisecond pulsar, the Shapiro delay would cause an observationally discernable shape distortion of the lensed pulses. The number of such observable systems is estimated. The result shows that there may be hundreds of such systems in our galaxy that are observable for a radio telescope with a sensitivity of $\sim 10\, mJy$. The model is applied to two recently found puzzling long-period radio sources: J162759.5-523504.3 and PSR J0901-4046. If these two sources are 52 self-lensed pulsar-BH systems, the BH mass will be $\sim 10^4$ and $\sim 10^2$ solar masses, respectively. Their coalescence time will become so small (~ year) that they should have merged by now.

Numerical study of AGN feedback at galactic scale

Type: Invited Talk

Primary Author: Feng Yuan

I will review wind launched from black holes, including their theoretical and observational evidences, main properties, driving mechanism, and its comparison with jet. While the talk will mainly focus on wind from a hot accretion flow, the cases of wind production from a standard thin disk and a super-Eddington accretion flow and the roles of wind played in AGN feedback will also be briefly introduced.

Binaries wandering around supermassive black holes due to gravitoelectromagnetism

Type: Poster

Primary Authors: Zhongfu Zhang

Co-author: Xian Chen

Extreme-mass-ratio inspirals are important sources for space-borne gravitational-wave detectors. Such a source normally consists of a stellar-mass black hole (BH) and a Kerr supermassive BH (SMBH), but recent astrophysical models predict that the small body could also be a stellar-mass binary BH (BBH).
A BBH reaching several gravitational radii of a SMBH will induce rich observable signatures in the waveform, but the current numerical tools are insufficient to simulate such a triple system while capturing the essential relativistic effects.

In this talk, I will solve the problem by studying the dynamics in a frame freely falling alongside the BBH. Since the BBH is normally nonrelativistic and much smaller than the curvature radius of the Kerr background, the evolution in the free-fall frame reduces essentially to Newtonian dynamics, except for a perturbative gravitoelectromagnetic force induced by the curved background.
I will use this method to study the BBHs on near-circular orbits around a SMBH and track their evolution down to a distance of 2–3 gravitational radii from the SMBH. The simulations reveal a series of dynamical effects that are not shown in the previous studies using conventional methods. The most notable one is a radial oscillation and azimuthal drift of the BBH relative to the SMBH. These results provide new insight into the evolution and detection of the extreme-mass-ratio inspirals containing BBHs.

Constraining the acceleration of moving binary black holes using gravitational wave

Type: Contributed Talk

Primary Author: Xinmiao Zhao

Co-author: Xian Chen

Binary black holes (BBHs) are one of the most important types of gravitational wave (GW) sources. Recent studies show that BBHs may form and merge in the vicinity of a supermassive black hole (SMBH), which results in overestimated masses of black holes due to gravitational and Doppler redshift. One of the distinctive features of these GW sources is that they are accelerating around the SMBH, and we can search for them by constraining their acceleration using GW signals. In this work, we treat the GW sources which give deviated results from general relativity in the inspiral-merger-ringdown (IMR) consistency test as candidates for potentially accelerating ones. We use the Bondi-Metzner-Sachs (BMS) transformation to construct the GW waveform of accelerating BBHs and use the Bayesian inference method to estimate these candidates' acceleration.

Explanation for the late-time radio flares in tidal disruption event

Type: Contributed Talk

Primary Author: Jialun Zhuang

Co-author: Guobin Mou, Rong-Feng Shen, Wenbin Lu

Close encounters between stars and black hole result in the tidal disruption of the stellar due to the huge tidal force exerted on it, an accident known as tidal disruption events (TDEs). Recently, a few tidal disruption events have shown late-time (years after discovery) radio flares that last hundreds of days with flux densities ranging from 1 to 100 mJy, such as ASASSN-15oi, AT2018hyz. Here we propose a scenario that the late-time radio flares may originate from the interaction of the TDE outflow with circumnuclear dense gas clouds (torus). Collision of the outflow with the torus leads to the formation of the bow shock, which accelerates the electrons, amplifies the magnetic field, and produces a late-time radio flare after TDE. We calculate the associated radio signature and compare them with the observations. We find a general consistency between the observations and predictions with reasonable parameters value. Determined by the distance of the torus and the velocity of the outflow, the late-time radio flares occur hundreds of days after TDE and they can peak at 10^39 erg/s, which is comparable to the observation. And the rise time is about hundreds of days which depends on the radius of the torus and the velocity of the outflow. Observations will play a key role in unveiling the nature of the late-time radio flare and a systematic study of a much larger sample would help understand the process responsible for it.