Abstract Book

Growing Black Holes: Accretion and Mergers

In memory of Sergio Colafrancesco

Kathmandu, 2022 May 15-20

Abstracts of submitted posters, contributed talks and invited review talks in alphabetical order. Contributions from local participants are highlighted at the end.

William Alston
European Space Agency, Madrid, Spain

Talk
Understanding super-Eddington accretion using quasi-periodic oscillations in AGN

Abstract: Active galaxies are known to vary on all time scales and in all wavebands, with the fastest variations observed in the X-ray band. This variability processes can be used to gain important insight into the feeding of supermassive black holes. Quasi-periodic oscillations (QPOs) are strong, coherent signals arising in the innermost regions of the accretion flow in black hole X-ray binaries. They provide important information on the black hole mass and spin, as well as the structure of the strongly-curved spacetime close to the event horizon. If the accretion process is scale invariant then QPOs should also be present in AGN, however these have been notoriously difficult to detect. The nearby, bright and super-critically accreting NLS1 galaxy, RE J1034+396, is well-known to harbour a robust an d persistent X-ray QPO. In 2021, we carried out a 1 mega-second XMM-Newton campaign to study the QPO mechanism in unprecedented detail. In this talk I will present new results on the detailed timing properties of the QPO and discuss the underlying model causing the observed oscillation. These findings have implications for tests of strong gravity across the black hole mass range as well as the physical processes occurring in the super-Eddington regime.

Richard Anantua
University of Texas at San Antonio, United States

Talk
Positron Emission Modeling of AGN: M87 and Sgr A*

A self-similar, stationary semi-analytic model based on jet regions of a high accuracy relativistic magnetohydrodynamics (HARM) simulation and including electrons, protons and positrons is applied to M87 between 43 GHz VLBA and 230 GHz EHT scales to constrain its particle composition. Synchrotron emission is related to the partial pressure of electrons and positrons emitting at the observed frequency, which, in turn, is related to the local magnetic pressure and plasma ion number density in the Constant Leptonic Beta Model. Positron-deficient jets with sub-equipartition electron betas are required to achieve observable degrees of circular polarization $V/I > 0.001$ for M87 in this model. A radiatively inefficient accretion flow (RIAF) model with positrons is then applied to the Galactic Center source Sgr A* to predict morphological and polarization signatures that may be discovered in next generation very long baseline interferometric observations. Photon annihilation into electron-positron pairs is among many processes often neglected in radiative transfer routines applied to general relativistic magnetohydrodynamic (GRMHD) simulations of jet/accretion flow/black hole (JAB) systems. To help bridge this gap, the Constant Leptonic Beta Model is incorporated into the general relativistic polarized radiative transfer postprocessor GRTRANS for simple, simulation-based jet and disk semi-analytic models.

M. Celeste Artale
University of Padova, Italy

Talk
The most likely host galaxies of a compact binary coalescence

Understanding which are the most likely host galaxies of gravitational-wave sources would provide us with

fundamental information to comprehend the nature of compact binaries in the era of gravitational-wave (GW) astronomy.
In this talk, I will present a novel method to investigate the host galaxies of binary compact objects, by combining catalogs from hydrodynamical cosmological simulations together with population synthesis models. I will discuss the probability that a galaxy hosts a compact binary coalescence as a function of its stellar mass and star formation rate across cosmic time (up to redshift ~6). My results show that there is a strong correlation between the stellar mass of the host galaxy and the merger rate per galaxy. Similar correlations, but weaker, are found with the star formation rate and with the gas metallicity. Moreover, early-type galaxies host the vast majority of compact binary mergers at low redshift. These results are crucial for low-latency searches of GW sources as they provide a way to rank galaxies inside the error box of a given GW detection, reducing the number of viable host candidates.

Geoff Beck
University of the Witwatersrand, South Africa
Talk
Primordial black hole dark matter and the Sunyaev-Zel'dovich effect

Primordial black holes are a much studied candidate for dark matter. In the mass regime where their conjectured Hawking evaporation is significant they have been subject to many constraints via X-rays, gamma-rays, and even radio emission. Previously the Sunyaev-Zel'dovich effect (SZE) has been considered to place limits on the primordial black hole abundance via the effects of their accretion of ambient gas. In this work we will present a novel means of placing such limits, using the SZE induced by electrons produced via Hawking radiation in galaxies and galaxy clusters.

Marco Berton
European Southern Observatory (ESO), Chile
Invited review talk
NLS1 galaxies and their rapidly growing black holes

Narrow-line Seyfert 1 (NLS1) galaxies are a subclass of active galactic nuclei (AGN) identified more than 30 years ago, but still not entirely understood. Their most distinctive feature is the narrowness of their permitted lines, which is not interpreted as a sign of obscuration as in other AGN, but is instead attributed to low rotational velocity around a relatively low mass black hole. Since their luminosity is comparable to that of typical broad-line Seyfert 1 galaxies, their Eddington ratio is high, suggesting that these objects are characterized by rapidly growing black holes. Interestingly enough, some of them have been detected in gamma-rays, a sign that they can harbor powerful relativistic jets. In this talk I will outline their main properties, and discuss how the presence of relativistic jets in them affects our understanding of jet physics. I will also show how many of their properties indicate that their true nature is that of young AGN in a recently triggered activity phase, and how they are connected to other classes of kinematically young sources. Finally, I will report on the recent discovery of relativistic jets in a handful of NLS1s completely invisible at low radio frequencies, whose emission is completely absorbed by ionized gas. This may suggest that a class of small-scale jets in AGN exists, and is still completely unexplored.

Dipanweeta Bhattacharyya
Indian Institute of Science Education and Research (IISER) Mohali
Talk
Cosmic spin and mass evolution of black holes and its impact

The evolution of the central black hole is mainly dependent on the processes of gas accretion, the capture of stars, mergers as well as electromagnetic torque. In the case of gas accretion in the presence of cooling sources, the flow is momentum-driven, after which the black hole reaches a saturated mass and subsequently, it grows only by stellar capture and mergers. We model the evolution of the black hole mass and spin with the initial seed mass and spin as a function of redshift in a ΛCDM cosmology. For the stellar capture, we have assumed a power-law density profile for the stellar cusp in a framework of relativistic loss cone theory that includes the effect of the black hole spin, Carter's constant, loss cone angular momentum, and capture radius. We discuss the dependence of the capture rate on these parameters and the predicted capture rates of $10^{-5} - 10^{-6}$ yr^{-1} are closer to the observed range. We have considered the merger activity to be effective for $z \lesssim 4$, while we include the effect of Blandford - Znajek torque for spin evolution,thus obtaining the joint black hole mass and spin evolution. We predict the impact of the evolution on the $M_{\bullet} - \sigma$ relation and compare our results with available observations. We also apply our evolution model to the specific cases of the quasars ULASJ134208.10+092838.61 (z=7.54), ULASJ112001.48+064124.3 (z=7.08) and DELSJ003836.10-152723.6 (z=7.02) and retrodict their formation parameters.

Gopal Bhatta
Institute of Nuclear Physics, Poland
Talk

Exploring long-term optical and gamma-ray variability properties of blazars

Blazars, a subset of powerful active galactic nuclei, feature relativistic jet which shine in a broadband electromagnetic radiation, e. g. from radio to TeV emission. Here I present the results of the studies that explore gamma-ray and optical variability properties of a sample of gamma-ray bright sources. Several methods of time-series analyses are performed on the decade-long optical and Fermi/LAT observations. The main results are as follows: The sources are found highly variable in both the bands, and the gamma-ray power spectral density is found to be consistent with flicker noise suggesting long-memory processes at work. While comparing two emission, not only the overall optical and the γ-ray emission are highly correlated but also both the observation distributions exhibit heavy tailed log-normal distribution and linear RMS-flux relation. Similarly, non-linear time series analysis suggested the presence of deterministic nature of the underlying dynamical processes. In addition, in some of the sources hints of quasi-periodic oscillation were revealed with similar characteristic timescales in the both the wave-bands. The results can be explained in light of current blazar models with relativistic shocks propagating down the jet viewed close to the line of sight.

Deepika Bollimpalli
Max-Planck Institute for Astrophysics, Germany
Invited review talk

Variability in discs around black holes: Broadband variability and QPOs

Long-term observations have shown that black hole X-ray binaries exhibit strong, aperiodic variability on time scales of a few milliseconds to seconds. In addition, these systems also exhibit rapid variability in their X-ray light curves termed quasi-periodic oscillations (QPOs); also broadly classified into high-frequency and low-frequency QPOs. Understanding the nature of these variabilities and the underlying physical processes helps us probe the nature of the compact object and its surroundings. In this talk, I shall give a broad overview of the existing theoretical models for broadband variability and different types of QPOs, with a focus on the findings from the current state-of-art simulations of accretion discs in reproducing such time variability phenomena.

In particular, I will discuss how the mass accretion rate fluctuations generated by the turbulence in the simulations naturally explain the observed broad-band variability in BHXRBs, and how the precession frequency of the inner geometrically thick disc differs from the standard Lense-Thirring precession frequency due to the surrounding geometrically thin disc present in a truncated disc geometry.

Stefano Bondani
University of Insubria, Italy
Talk
Gravitational Waves from Primordial Black Holes at the Galactic Center

In our work we characterized the expected gravitational wave signal detectable by the planned space-borne interferometer LISA and the proposed next generation spaceborne interferometer muAres arising from a population of primordial black holes orbiting SgrA*. Assuming that such objects indeed form the entire diffuse mass allowed by the observed orbits of stars in the Galactic center (<4 x 10^3Msol within a radius of 10^-3 pc from SgrA*), under the simplified assumption of circular orbits and monochromatic mass function, we assessed the expected signal in gravitational waves, either from resolved and non-resolved sources.

Luciano Burderi
Università di Cagliari
Invited review talk
CubeSats and Distributed Astronomy: from the HERMES fleet to the flight of the ALBATROS, surfing the waves of quantum space-time

ALBATROS (Astonishingly Long Baseline Array Transients Reconnaissance Observatory in Space) is an ambitious astro- physical mission concept that uses a fleet of three small satellites to create an high-energy all-sky monitor with excellent localisation capabilities. The proposed orbits for the spacecrafts are three independent Earth-trailing heliocentric orbits, that will form a nearly equilateral triangular formation with 2.5 106 km arm length: the so-called cart-wheel formation. Each satellite is equipped with two opposite facing ∼ 500 cm2 effective area detectors each consisting of a segmented array of crystal scintillators (GAGG) with a half-sky Field of View, keV-MeV energy band, and temporal resolution better than one microsecond. Thanks to the million km baselines, temporal triangulation techniques allow unprecedented location accuracies, few arc-second/few arc-minutes, for bright/faint transients in a wide energy band, few keV-few MeV crucial for hunting the elusive electromagnetic counterparts of Gravitational Waves, that will play a paramount role in the future of Multi-messenger Astronomy.
This project is an example of high-energy distributed astronomy: a new concept of modular observatory consisting of a fleet of small satellites displaced over a large array, with sub-microsecond time resolution and wide energy band (keV-MeV). A pathfinder of ALBATROS is already under development through the HERMES (High Energy Rapid Modular Ensemble of Satellites) and SpIRIT (Space Industry Responsive Intelligent Thermal Nanosatellite) projects: a fleet of six 3U cube-sats (HERMES) to be launched by the end of 2023 plus one 12U cube-sat (SpIRIT) to be launched by the end of 2022.
ALBATROS will furnish the golden sample of GRBs needed to test the dispersion law theorised by some Quantum Gravity theories, which predict relative discrepancies of the speed of photons w.r.t. the speed of light proportional to the ratio of the photon energy to the Planck energy. This effect is extremely small, and GRBs occurring at cosmological distances represent the ideal target to explore it. We describe a compelling approach to this problem that statistically combines a large number of GRBs for which light-curves of the prompt emission over a wide energy band (keV-MeV) are available, and distances are known. We discuss how a golden sample of ∼ 1000 GRBs with known redshift is sufficient to effectively constrain this

dispersion law.

Igor Chilingarian
Center for Astrophysics - Harvard and Smithsonian
Talk
AGN powered by intermediate-mass black holes: what can they tell us about the supermassive black hole growth

Nearly every massive galaxy harbors a supermassive black hole (SMBH) in its nucleus, The origin of SMBHs remains uncertain: they could have emerged either from massive ``seeds'' (100k-1M MSun) formed by direct collapse of gas clouds in the early universe or from smaller (100 MSun) stellar mass BHs. The latter channel would leave behind numerous intermediate-mass BHs (IMBHs, 100-100kMSun). Using data mining in wide-field sky surveys and applying dedicated analysis to optical spectra, we identified hundreds of IMBH candidates, which reside in galaxy centers and are currently accreting gas that creates optical signatures of type I AGN. 25 candidates were confirmed by X-ray emission as bona fide IMBHs as of now. In the follow-up campaign, we identified 7 IMBHs accreting close to the Eddington limit. We also re-measured virial masses for about 120 X-ray confirmed ``light-weight'' BHs (below 1M MSun) and constructed scaling relations between SMBHs and their host galaxies (MBH--sigma and MBH--Mbulge) in the light-weight regime. We will discuss how different channels of black hole growth and mass assembly of their host galaxies affect the observed scaling relations. The very existence of numerous nuclear IMBHs supports the stellar-mass seed scenario of the massive BH formation.

Giovanni Cresci
INAF - Arcetri Observatory
Talk
The physical properties of AGN outflows and their impact on host galaxies

Feedback from AGN is considered the main physical mechanism to quench star formation in galaxies, at least at the high mass end of the galaxy population. This feedback is believed to operate through powerful, massive outflows driven by the energy release operated by the AGN. However, while outflows are ubiquitous in AGN, their origin, impact on host galaxies and properties are still poorly known. In particular, measurements of the outflow physical properties still rely on very rough assumptions which must be overcome when dealing with the wealth of information provided by the new integral field spectroscopic observations.
I will present the results from detailed observations of outflows in local galaxies in the framework of the MAGNUM MUSE survey, aimed to understand the physical properties of the outflows and their impact on the host galaxies. I will also present galaxy scale ionised outflows in four Ultra Fast Outflows hosts, showing relativistic X-ray winds observed at the nuclear scale. The momentum rates of these ionised outflows are comparable to those measured for the UFOs at sub-pc scales, indicating momentum-driven wind propagation, and discuss the implications of these findings.

Alejandro Cruz-Osorio
Goethe University Frankfurt, Germany
Invited review talk
The shadow of the supermassive black hole in M87

The Event Horizon Telescope (EHT) has observed for the first time the central compact radio source of the elliptical galaxy M87 at 1.3 mm with unprecedented angular resolution. These images show a prominent ring with a diameter of ~40 micro-arcsecond, consistent with the size and shape of the lensed photon orbit encircling the "shadow" of a supermassive black hole. We constructed a large library of models based on general relativistic magnetohydrodynamic simulations and synthetic images produced by general relativistic ray tracing. We compare the observed visibilities with this library and confirm that the asymmetric ring is consistent with earlier predictions of strong gravitational lensing of synchrotron emission from a hot plasma orbiting near the black hole event horizon. Overall, the observed image is consistent with expectations for the shadow of a spinning Kerr black hole as predicted by general relativity. If the black hole spin and M87's large-scale jet are aligned, then the black hole spin vector is pointed away from Earth. Models in our library of non-spinning black holes are inconsistent with the observations as they do not produce sufficiently powerful jets. Finally, I will discuss the magnetic field morphology inferred from polarization observed images.

Rohan Arun Dahale
Instituto de Astrofisica de Andalucia (IAA-CSIC), Spain
Talk
Faraday Rotation in Parsec-scale AGN Jets

We report the Faraday rotation analysis for three sources: BL Lac, 0716+714, and 3C 120 using astrometric multi-frequency Very Long Baseline Array (VLBA) observations. The observations were carried out at three different epochs between 2013 and 2014 at six frequencies between 5 and 86 GHz. The linear polarization and rotation measure (RM) maps using these observations allow us to analyze the magnetic field in the jets of different AGN at different spatial scales and hence enable us to understand the jet formation and stability. The calibration of the absolute electric field vector position angles was obtained through comparison with the quasi-simultaneous observations of our targets obtained with the Effelsberg single dish (F-GAMMA program) at 5 and 8 GHz, VLBA-MOJAVE at 15 GHz, VLBA-BU at 43 GHz, and IRAM single dish (POLAMI program) at 86 GHz. We expect a gradient in the rotation measure maps and the intrinsic polarization vectors to support models showing a helical magnetic field in the jets.

Mariia Demianenko
Sternberg Astronomical Institute, Russia
Talk
Optical variability analysis of IMBH candidates using ZTF time series

Time-domain surveys with frequent cadence provide a unique opportunity to detect and explore variability and anomalies of millions of sources on different timescales. Broadband photometric variability can be used as the key selection criteria for weak type-I active galactic nuclei (AGN), when other "direct" confirmation criteria like X-ray or radio emission are unavailable. However, light curves from The Zwicky Transient Facility (ZTF) data releases without difference photometry cannot be useful for obtaining statistical information about optical variability of such objects. Since variability of rather weak AGN powered by intermediate-mass black holes (IMBHs) is about few percent, and host galaxies overlap small effects. We developed an algorithm for post-processing of difference image light curves for sources with stochastic variability, obtained from the ZTF Forced Photometry service. We can now confidently detect the broad-band variability at the few percent level which can potentially be used as a substitute for expensive X-ray follow-up observations. Moreover, we analyzed the optical variability of the sample from the previously found optical wide lines IMBHs.

Valerio D'Elia
ASI Space Data Centre

Poster

GRB 171205A/SN 2017iuk: A local low-luminosity gamma-ray burst

Gamma-ray bursts (GRBs) occurring in the local Universe constitute an interesting sub-class of the GRB family, since their luminosity is on average lower than that of their cosmological analogs. Attempts to understand in a global way this peculiar behaviour is still not possible, since the sample of low redshift GRBs is small, and the properties of individual objects are too different from each other. In addition, their closeness (and consequently high fluxes) make these sources ideal targets for extensive follow-up even with small telescopes, considering also that these GRBs are conclusively associated with supernova (SN) explosions.
We aim to contribute to the study of local bursts by reporting the case of GRB 171205A. This source was discovered by Swift Burst Alert Telescope (BAT) on 2017, December 5 and soon associated with a low redshift host galaxy (z = 0.037), and an emerging SN (SN 2017iuk).
We analyzed the full Swift dataset, comprising the UV-Optical Telescope (UVOT), X-ray Telescope (XRT) and BAT data. In addition, we employed the Konus-Wind high energy data as a valuable extension at γ-ray energies. The photometric SN signature is clearly visible in the UVOT u, b and v filters. The maximum emission is reached at ̃13 (rest frame) days, and the whole bump resembles that of SN 2006aj, but lower in magnitude and with a shift in time of +2 d. A prebump in the v-band is also clearly visible, and this is the first time that such a feature is not observed achromatically in GRB-SNe. Its physical origin cannot be easily explained. The X-ray spectrum shows an intrinsic Hydrogen column density NH,int = (7.4+4.1-3.6)E20 cm-2, which is at the low end of the N H, int, even considering just low redshift GRBs. The spectrum also features a thermal component, which is quite common in GRBs associated with SNe, but whose origin is still a matter of debate. Finally, the isotropic energy in the γ-ray band, Eiso = (2.18+0.63-5.0)E49 erg, is lower than those of cosmological GRBs. Combining this value with the peak energy in the same band, Ep = 125+141-37 keV, implies that GRB 171205A is an outlier of the Amati relation, as are some other low redshift GRBs, and its emission mechanism should be different from that of canonical, farther away GRBs.

Gulab Dewangan
IUCAA, Pune
Invited review talk

Highlights of the AstroSat mission

AstroSat is India's first multi-wavelength space astronomy mission, launched on 28 September 2015. AstroSat carries four co-aligned scientific payloads that perform observations in the optical, ultraviolet, soft and hard X-rays. The four payloads are (i) a Soft X-ray Telescope (SXT), (ii) three Large Area X-ray Proportional Counters (LAXPCs), (iii) a Cadmium-Zinc-Telluride Imager (CZTI), and (iv) two Ultra-Violet Imaging Telescopes (UVITs), one for visible and near-UV channels and another for far-UV. AstroSat is a proposal-driven observatory with observing opportunities available to national and international scientists. AstroSat has observed more than 1400 targets. These observations have resulted in more than 200 refereed publications. This talk will highlight the main results obtained from multi-wavelength UV/X-ray observations of active galactic nuclei and X-ray binaries.

Akash Garg
Jamia Millia Islamia, India
Talk

Modelling the energy dependent fractional rms and time lags in MAXI J1535-571 as observed by AstroSat

Numerous timing studies in the past have shown that Blackhole X-ray binaries possess rapid X-ray variability during their outburst period. In Fourier space, such variations are seen as narrow peaks known as Quasi-periodic oscillations(QPOs) along with broadband noise components. There have been attempts to explain observed behaviour either by geometric origin or by identifying radiative components that can give rise to them. For the latter one, it is needed to carry out the spectral analysis and determine spectral parameters which then needs to be translated into physical ones to obtain interpretation for accretion disk around black holes in the systems. The variations in these parameters can then be chosen numerically to produce the energy-dependent properties related to QPOs. Since LAXPC and SXT onboard AstroSat provides a broad energy range for spectral analysis along with better timing resolution of LAXPC, we chose AstroSat observations of low-frequency QPOs in MAXI J1535-571 and fitted the observed behaviour with a theoretical one. We found that variations in accretion rate, inner disk radius, coronal optical depth and heating rate along with time delays between them can explain the variability.

Andreja Gomboc
University of Nova Gorica, Slovenia
Invited review talk
Observing Tidal Disruption Events with Vera Rubin Observatory LSS

The upcoming Vera C. Rubin Observatory Legacy Survey of Space and Time (Rubin LSST) is a revolutionary project, which will produce an unprecedented astronomical survey of our Universe. Using an 8.4-meter telescope in Chile with the field of view of 9.6 deg^2, reaching limiting magnitude r=24.4 in single exposure, it will carry out 10-year long survey of the dynamic Universe in six optical bands, thus creating a multi-colour "movie" of the Universe. It will repeatedly image to great depth the entire visible sky in just a few nights and detect thousands of new, transient sources per night, including tidal disruptions of stars by supermassive black holes.
I will address the prospects of Rubin LSST in discovering tidal disruption events (TDEs), significantly enlarging their sample, and probing the supermassive black hole mass distribution. I will also present a metric for the evaluation of proposed Rubin LSST observing strategies' performance developed specifically for TDEs, and discuss challenges of TDE identification in Rubin LSST era.

Rosa Amelia Gonzalez-Lopezlira
UNAM, Campus Morelia, Mexico
Talk
The globular cluster system of Messier 106, correlated with the supermassive black hole and a relic of cosmic high noon

We present multi-object spectroscopic observations of 23 globular cluster candidates (GCCs) in the prototypical megamaser galaxy NGC 4258, carried out with the OSIRIS instrument at the 10.4 m Gran Telescopio Canarias. The candidates have been selected based on the (u* - i') versus (i' - Ks) diagram, in the first application of the \uiks\ method to a spiral galaxy. In the spectroscopy presented here, 70% of the candidates are confirmed as globular clusters. Our results validate the efficiency of the \uiks\ method in the sparser GC systems of spirals, and the agreement of the galaxy with the correlations between black hole mass, and total number and mass of GCs. We find that the metal-poor GCs co-rotate with the HI disk, even at large galactocentric distances. The ratio of rotation to velocity dispersion V/sigma of the system is ~ 1, consistent with the highly turbulent, rotating disks at z>=2 that constitute nowadays the favored environment for the formation of globular clusters. This system could be a z = 0 relic of this process.

Achamveedu Gopakumar (tbc)
Tata Institute of Fundamental Research
Invited review talk
The blazar OJ287 and its nano-Hertz GW emitting massive BH binary central engine

Blazars are active galactic nuclei with strong jets. They tend to exhibit dramatic and unpredictable flux variations, namely outbursts. Certain observed outbursts from an exceptional Blazar OJ287 can be explained by invoking a massive black hole binary as its central engine.
Detailed General Relativistic modeling allowed us to predict a major optical outburst during November 2015. The outburst did occur within the expected time range, peaking on 5/12/2015. A multi-wavelength observational campaign confirmed the occurrence of certain impact flare and the presence of a major thermal component in the flare, as predicted. These observations and subsequent analysis allowed us to establish the possible presence of a spinning supermassive black hole binary that spirals in due to the emission of nano-Hertz gravitational waves in the central engine of OJ287. I will briefly list our on-going efforts that should be interesting to the Event Horizon Telescope consortium and the International Pulsar Timing Array.

Vladimir Goradzhanov
Sternberg Astronomical Institute
Talk
Scaling relations of Intermediate Mass Black Holes and their host galaxies

Intermediate-mass black holes (IMBHs; MBH < 200k Msun) in galaxy centers are crucial for painting a coherent picture of the formation and growth of supermassive black holes (SMBHs). Using Big Data analysis, we identified 305 IMBH candidates for IMBH and 1623 candidates of ‘light-weight’ SMBHs (200k < MBH < 1M MSun). For 35 host galaxies from this combined sample with the X-ray-confirmed active galactic nuclei (AGN) we collected and analyzed optical spectroscopic observations with intermediate-resolution optical spectrographs MagE (6.5-m Magellan telescope), RSS (10-m Southern African Large Telescope), and ESI (10-m Keck telescope). These data show that bulge stellar velocity dispersions lie in the range of 24...118 km/s and follow the correlation with MBH established by larger SMBHs.

Ore Gottlieb
Northwestern University
Invited review talk
Revealing the physics of black hole powered transients

I will present the first 3D GRMHD collapsar simulations, which extend from a self-consistent jet launching by an accreting Kerr black hole (BH) to the emission zone, over 6 orders of magnitude with the highest resolution of a GRB simulation to date. Showing three types of emerging outflows that depend on the angular momentum of the collapsing material and the magnetic field on the BH horizon, our results suggest that the wide variety of observed explosion appearances (supernova/supernova+GRB/low-luminosity GRBs) and the characteristics of the emitting relativistic outflows (luminosity and duration) can be naturally explained by the differences in the progenitor structure. The jet evolution revealed by the simulations could transform our understanding of GRBs, as it exhibits strong magnetic dissipation inside the star, resulting in hydrodynamic jets at the emission zone; and spontaneous tilt of the disk-jet that leads to wide angle precession, which in turn suggests that GRB volumetric rate is low and most jets are choked. I will finish with showing how this result is a natural solution to the entire set of fast blue optical transient (FBOT) observables, from X-ray to radio emission.

Jonathan Granot
The Open University of Israel
Invited review talk
Binary Neutron Star Mergers - Insights from Multi-Messenger observations

The first detection of a gravitational wave signal from a binary neutron star merger, GW 170817, was accompanied by an electromagnetic counterpart in the form of a short duration gamma-ray burst, GRB 170817A. An impressive global effort of multi-wavelength follow-up observations has led to the detection of kilonova emission in the optical, UV and NIR, as well as long-lived X-ray to radio afterglow emission. This unique event has a wide range of implications ranging from constraints on the neutron star equation of state and maximal mass, through the important role of such binary mergers in r-process nucleosynthesis in the universe, to the type of remnant that was produced, and the properties of the outflows that are produced in these mergers. This review will focus on what it has taught us about the properties of the outflow that powered the prompt gamma-ray emission and the afterglow emission, and briefly outline the constraints on the type of compact remnant (black hole or massive neutron star) that was left in its aftermath. Finally, some future prospects on what may be learned from binary merger multi-messenger observation will be outlined.

Kirill Grishin
APC, AstroParticule et Cosmologie, University of Paris
Talk
Structural Properties and Environment of Galaxies Hosting AGN Powered By Low-mass Black Holes

There are two channels of SMBH growth: accretion of infalling material and galaxy mergers leading to the mergers of central black holes. The latter way of growth leads to scaling relations between central black hole mass and intrinsic properties of the host galaxy (e.g. bulge stellar mass, velocity dispersion of stars in a bulge). Our goal is to populate these relations at the low-mass end (<1M MSun including intermediate-mass black holes <200k MSun). We study the environment and structural properties of host galaxies for a sample of 305 IMBH candidates identified by Chilingarian et al. (2018) complemented with slightly more massive black holes. Low-mass BHs tend to reside in low density environments. We followed up over 40 galaxies using FourStar NIR imager at the 6.5-m Magellan telescope. We obtained the total bulge stellar masses from the 2D photometric decomposition. Our results demonstrate that host galaxies of AGN powered by low-mass BHs follow scaling relation set by more massive SMBHs. This supports the scenario of BH and host galaxy co-evolution in the low-mass regime.

Nazma Husain
Jamia Millia Islamia University, India
Low-frequency break detection in hard state of GX 339-4 with AstroSat

We report detection of a characteristic low-frequency (mHz) break in the power density spectrum (PDS) of GX 339-4 in the faint low/hard state observations, which were extracted at the beginning of two outbursts of 2017 and 2019 with AstroSat. The energy spectrum of both observations could be described with an absorbed power-law of a nearly equal photon index of 1.57 and 1.58 and with Eddington ratio, L/L Edd, of 0.0011 and 0.0046, respectively. The X-ray continuum also showed weak reflection features, which were accounted with reflection components leading to improvement in χ^2 fit ($\Delta\chi^2 \approx 6$ for 2017 and $\Delta\chi^2 \approx 7$ for 2019). With analysis of the timing properties, mHz break was observed in the PDS at 6 mHz for 2017 and at 11 mHz for 2019 observation, whose detection is validated by results from independent detectors (LAXPCs and SXT). These detections and the flux levels are consistent with earlier results of the source done in similar hard state. The physical description of the break frequency can be understood using the disk truncated model, which associates this frequency with the viscous time scale at the truncation radius. Using this approach, we also constrain the truncation radius to be 93 and 61 gravitational radii for 2017 and 2019 observation, respectively.

Danat Issa
Northwestern University
Poster
Simulating neutron star merger remnant outflows with a two-moment neutrino scheme

Neutron-star (NS) mergers provide unique environments for mass accretion, ejection, and r-process nucleosynthesis. Information about the NS merger and its outcome is encoded in the observed electromagnetic (EM) signatures, such as gamma ray bursts, kilonova and afterglow emissions. To boost the scientific return from these observations, we need first-principle models to quantitatively interpret them. Here, I will present results of the first long-duration (~ few seconds) high resolution 3D general relativistic magnetohydrodynamic (GRMHD) simulation of the merger aftermath including (a) accurate neutrino transport with (b) realistic equation of state and (c) realistically weak seed magnetic fields, which will allow me to the predict EM emission from from first principles. Moreover, I will enhance the realism of the simulations by initializing them with an outcome of a fully general relativistic merger simulation.

Jonatan Jacquemin
Center for Interdisciplinary Exploration & Research in Astrophysics (CIERA), Northwestern University, USA
Invited review talk
Magnetized turbulence, accretion and outflows

Accretion disks around black holes, like X-ray binaries or AGN, feature complex emission properties and intricate secular evolution, like outburst. Furthermore, outflows launched from the accretion disk lead to absorption lines modifying the emission properties. The emission and the secular evolution depend on the accretion rate. Hence, understanding the transport properties of the disk is essential.
The only efficient driver of accretion within the accretion disk is the torque due to a magnetic field. This torque can be (1) laminar, driven by the large-scale topology of the magnetic field, or (2) turbulent, driven by the MRI-driven turbulence.
While the turbulent magnetic field only drives accretion, the large-scale magnetic field drives outflows from the disk and the BH. To understand accretion, we need to understand the properties of the average and turbulent magnetic fields and their non-linear coupling, which are hard to grasp.
In this talk, I will first review the properties of turbulent and laminar accretion. Then, I will describe how the MRI turbulence modifies the vertical equilibrium and the large-scale topology of the magnetic field. Then I will discuss the role of MRI turbulence in generating a large-scale magnetic field through a dynamo-like mechanism.

Bestin James
Center for Theoretical Physics, Polish Academy of Sciences
Poster
GRB jet structure and variability studies with 3D simulations of magnetically arrested disks

We study the structure and temporal variability properties of the GRB jets considering a magnetically arrested disk as their central engine. We numerically evolve the accretion disk around a Kerr black hole using 3D general relativistic magneto-hydrodynamic simulations. We consider two analytical equilibrium disk configurations, the Fishbone-Moncrief and Chakrabarti solutions, as the initial conditions and impose poloidal magnetic fields upon them. The disk starts accreting due to the development of the magneto-rotational instability and eventually develops to a magnetically arrested accretion disk state. We consider these models to be central engines of short and long-GRBs, based on our initial conditions, and investigate the properties of the jets launched from these models. Our models self-consistently produce structured jets with a hollow core up to ~ 5 degrees. The jets from our simulations have an opening angle up to ~ 11 degrees for the long-GRB model and up to ~ 25 degrees for the short-GRB model. We also do the time variability studies of the jets and provide an estimate of their minimum variabilty timescales. Our models can be applied to the GRB jets in the binary neutron star post-merger system or to the ultra-relativistic jets launched from collapsing stars.

Agnieszka Janiuk
Center for Theoretical Physics PAS, Poland
Invited review talk

Structure and Variability of Magnetically Dominated Jets from Accreting Black Holes

Energy extraction from the rotating black holes is a viable mechanism for explaining the power of relativistic jets, observed from stellar mass to the supermassive black hole scale. In Gamma Ray Bursts, the structured jets have recently been invoked to explain their complex emission. In particular, the source GW170817 is an example of a structured jet, observed off-axis and interacting with the post-merger ejecta and accretion disk wind. Observational studies have also shown an anticorrelation between the jet variability, measured by its minimum timescale, and the Lorentz factor. The correlation spans several orders of magnitude, from blazars to GRBs scales. Finally, power density spectral slopes of GRBs variability seem to be correlated with their peak energies.
The variability of a jet manifested on different timescales may be driven by central engine instabilities, imposed by strong magnetic fields in a magnetically arrested state, and by the jet interactions with its environment. I will discuss and review the recent developments of the jet and central engine models, with particular focus on the results of GR MHD simulations. I will also present observational constraints for these models.

Emilia Järvelä
ESA / European Space Astronomy Centre, Spain
Talk

Extended radio emission in narrow-line Seyfert 1 galaxies

Narrow-line Seyfert 1 galaxies (NLS1) are an intriguing class of gamma-ray emitting active galactic nuclei (AGN). Contradictory to the traditional jet paradigm NLS1s mostly reside in spiral galaxies, harbor low or intermediate mass black holes, accreting at high Eddington ratio, and show preferably compact radio morphologies. These properties suggest that NLS1s are young AGN, possibly going through one of their very first activity cycles.
However, NLS1s have proven to be a very heterogeneous class of sources: a handful of them are able to maintain powerful relativistic jets, but the majority has not even been detected in radio frequencies.
Recent radio imaging surveys targeting NLS1s have found that a considerable fraction of radio-detected NLS1s exhibit kpc-scale radio emission, and even diffuse emission resembling radio relics has been found, possibly indicating intermittent nuclear activity. These sources often belong to the radio quiet population, and might, in part, help explain the observed diversity of NLS1s. Studying their radio, as well as other properties is crucial to continue building a comprehensive picture of the NLS1 population, and to better understand the activity and duty-cycle of efficiently accreting supermassive black holes.
Here we present a detailed study of a sample of NLS1s with extended radio emission found in our earlier JVLA survey. We used optimal tapering to reveal low-intensity kpc-scale radio emission, and, for example, in-band spectral index maps to investigate its nature. Combined with additional available data, we discuss how these sources fit into our current understanding of NLS1s, and the AGN phenomena in general.

Nick Kaaz
Northwestern University
Talk
Jet Formation in GRMHD Wind Tunnel Simulations

In various astrophysical scenarios, a black hole (BH) propagates through dense, gaseous media. These include BHs wandering through the interstellar medium, wind accretion in binary systems, and BH common envelope evolution. Most treatments of accretion phenomena such as these are purely hydrodynamic, while in reality most astrophysical plasmas are at least weakly magnetized, and an accreting BH can produce significant feedback which alters the surrounding gas supply. In my recent work, I have performed 3D, general-relativistic magnetohydrodynamics simulations of wind accretion onto rapidly rotating black holes using the code H-AMR. I have found that the ensuing accretion continuously drags to the BH the magnetic flux, which accumulates near the event horizon until it becomes dynamically important. Depending on the strength of the background magnetic field, the BHs can sometimes launch relativistic jets with high enough power to drill out of the inner accretion flow, become bent by the headwind, and escape to large distances. While for stronger background magnetic fields the jets are continuously powered, at weaker field strengths they are intermittent, turning on and off depending on the fluctuating gas and magnetic flux distributions near the event horizon. I found that the jets reach extremely high efficiencies of $\sim$100−300% , even in the absence of an accretion disk. I also calculated the drag forces exerted by the gas onto to the BH, finding that the presence of magnetic fields causes drag forces to be much less efficient than in unmagnetized wind accretion, and sometimes become negative, accelerating the BH rather than slowing it down.

Ivan Katkov
New York University Abu Dhabi, United Arab Emirates
Talk
Multi-wavelength view of large-scale galactic outflows

Galaxy-scale outflows are an important component of galaxy evolution models. Nevertheless, how they affect the host galaxy’s star formation and metal enrichment histories remain unclear. Such outflows are currently thought to be generated by Active Galactic Nucleus (AGN) and starburst activity. Both mechanisms can produce hot gas and relativistic particles, which generate radio and optical emission. In this project, we are combining optical integral-field spectroscopy data from the MaNGA survey and sensitive radio (Jansky Very Large Array; JVLA) observations to measure the properties of both components with comparable (~1-2”) angular resolution. In the talk we will present a joint analysis of the radio morphology and spectrum, ionized gas kinematics, and the properties of the host galaxy for a sample of 30 targets including AGN, starbursts, and composite sources whose optical spectrum indicate high-velocity components in the [OIII] emission line. We demonstrate how, together, spatially resolved radio and optical data offer a more complete picture of the outflow’s energetics, kinematics, origin, and interaction with their surroundings.

Michael Kavic
SUNY Old Westbury, United States
Talk
Accessing the axion via compact object binaries

Tests of ideas at the frontier of physics, whether in the realm of dark matter detection or quantum gravity, are hard to conduct on Earth. For example, accelerator energies are many orders of magnitude too low to directly test GUT-scale physics and the even more prohibitive compactification scale of extra spatial dimensions. But astrophysical “laboratories” have no such limits. On the other hand, astrophysical systems can be complex. We will discuss a relatively “simple” binary system consisting of a Kerr black hole and pulsar. The pulsar, acting as a precision orbiting clock, would enable measurements that can test specific predictions beyond the standard model. This talk will consider the case of black hole super radiance which allows axions to be generated in a cloud around a Kerr black hole. This cloud drains the rotational kinetic energy, and thus mass, emitting gravitational waves in the process. Axions are central to many theoretical ideas at the frontier of physics including as a dark matter candidate and are a prediction of models of quantum gravity such as string theory. We will discuss how precision measurements of the changing orbital period of the system (at the level accomplished in the case of the binary pulsar) can test this axion production process, and set limits on the mass scale of the axions produced. The Square Kilometer Array will be able to discover and observe black hole-pulsar binaries and will be able to search for axions in such systems.

Rubinur Khatun
National Centre for Radio Astrophysics - Tata Institute of Fundamental Research (NCRA-TIFR)
Talk
Searching for dual AGN in galaxy mergers and their effect on galaxy evolution

Cosmological simulations of merging galaxies have demonstrated that mergers lead to triggering AGN, enhanced star-formation and an alteration of interstellar medium (ISM) properties. One of the expected outputs of galaxy mergers are pairs of AGN. A detailed study of a large sample of dual AGN (DAGN) observed over a range of separations can help us to understand the growth of SMBH, the feedback associated with DAGN, and the evolution of the galaxies. We have compiled a sample of 20 double-peaked AGN (DPAGN) from the literature and observed them at multiple frequencies with the Karl G. Jansky Very Large Array (VLA). One of the sources, 2MASXJ1203, shows prominent S-shaped radio jets. From a spectral aging analysis and fitting of the precession model, we have concluded that the S-shaped jets are due to a binary/dual SMBH system with a separation of ~0.02pc or a single SMBH with a tilted accretion disk. For three other DPAGN sources in our sample, we have detected dual-radio structures at a separation of ~10 kpc. Using radio spectral index images and optical spectra, we have confirmed that one of them is a DAGN. We have found that the double-peaked lines do not always originate in DAGN but could be due to outflows/jets instead. We have concluded that DPAGN identified in low-resolution SDSS spectra are not good indicators of DAGN. On the other hand, closely interacting galaxies or merger remnants are good candidates for detecting DAGN. We have carried out multi-wavelength studies with the VLA,Ultra-violet imaging telescope (UVIT), Himalayan Chandra Telescope (HCT), and Giant Metrewave Radio Telescope (GMRT) to confirm the nature of the nuclei of the dual-nuclei merger system MRK212; both nuclei turn out to be AGN. We have detected star-forming knots in UV near the centre of one AGN; star-formation could have been induced by the ongoing merger or AGN feedback. In this presentation, I will show the results from our multi-wavelength study of dual AGN candidates in detail.

S. Komossa, D. Grupe, A. Kraus, et al.
Germany
Poster
Project MOMO: Multimessenger astrophysics of the blazar and candidate binary SMBH OJ 287

We present results from our ongoing multi-wavelength observations and modelling of the blazar and candidate binary supermassive black hole (SMBH) OJ 287, obtained in the course of the MOMO project (Komossa et al. 2017, 2020, 2021a-d, 2022). The project provides us with the densest long-term multi-wavelength monitoring of the blazar OJ 287, or any binary SMBH candidate, ever obtained. The Neil Gehrels Swift observatory and the Effelsberg 100m radio telescope are at the heart of the project, along

with dedicated deep follow-up observations with XMM-Newton, NuSTAR and at optical telescopes, that are combined with public Fermi gamma-ray observations. MOMO provides us with timing information, spectroscopy, SEDs, and a variety of other information at all activity states of OJ 287, giving important new insights into disk-jet physics of this nearby bright blazar, and on the mechanisms of gamma-ray emission. Further, the results are used to test predictions of the binary SMBH model of OJ 287. The gravitational wave emission of this system is expected to be detectable with future pulsar timing arrays in the SKA era, making OJ 287 a key target for multimessenger astrophysics.

Orsolya Kovács
Masaryk University, Faculty of Science, Czech Republic
Poster

Searching for AGN in ultra-diffuse galaxies

Ultra-diffuse galaxies (UDGs) are curious objects that have unusually large extent relative to their low-surface brightness. These galaxies have been detected in large numbers in the Coma cluster, which hosts at least 800 UDGs. Although a number of studies attempted to study their origin, it remains unclear whether UDGs host supermassive black holes. In this project, we utilized Chandra X-ray and Subaru Hyper Suprime-Cam observations to search for actively accreting black holes in UDGs residing in the Coma cluster. We find two UDGs that have an X-ray source at 3.0" and 3.2" off-center position. In addition, we measure the AGN occupation fraction of dwarf and normal galaxies in the Coma cluster, which galaxies serve as a control sample. We confront the AGN occupation fraction of the control sample galaxies with that obtained for UDGs.

Ivan Kuzmin
Sternberg Astronomical Institute
Talk

Analysis of 1 million spectra from the RCSED catalog for virial estimation of the masses of the central black holes of galaxies

The search for low-mass black holes (IMBH, $M_{BH} < 2*10^5 M_{Sun}$ and LWSMBH $2*10^5 < 10^6 M_{Sun}$) is important for understanding galaxy evolution. In this work we analyzed the emission lines in the spectra of galaxies obtained from the RCSED catalog. Due to the developed method of 1d nonparametric analysis of emission lines in galaxy spectra we obtained virial estimates of masses of central black holes of galaxies with active nuclei. Further the objects for the search of IMBH and LWSMBH were qualified, namely, by the signal-to-noise ratio, χ^2 value, position in the BPT diagram, as well as by the quality of the broad components of the hydrogen lines of the Balmer series. The work resulted in finding new LWSMBH candidates (1928, of them 305 IMBHs), their virial estimates of mass, kinematic parameters of emission lines of spectra, as well as parameters of stellar populations. Also in the process of developing the second version of the RCSED catalog we have analyzed more than 150 thousand spectra of galaxies at
various redshifts. Thanks to the algorithm developed in this way, 26 new IMBH candidates have been found. As the RCSEDv2 catalog expands, the number of IMBH candidates is expected to increase 1.5-2 times as much as in the RCSED catalog.This sample will allow us to find features in the formation of low-mass black holes.

Aretaios Lalakos
Northwestern University, CIERA
Talk

Bridging Bondi and Event Horizon Scales: 3D GRMHD Simulations Reveal X-Shaped Radio Galaxy

Morphology

X-shaped radio galaxies (XRGs) produce misaligned X-shaped jet pairs and make up <~10% of radio galaxies. XRGs are thought to emerge in galaxies featuring a binary supermassive black hole (SMBH), SMBH merger, or large-scale ambient medium asymmetry. We demonstrate that XRG morphology can naturally form without such special, preexisting conditions. Our 3D general-relativistic magnetohydrodynamic (GRMHD) simulation for the first time follows magnetized rotating gas from outside the SMBH sphere of influence of radius R_B to the SMBH of gravitational radius R_g, at the largest scale separation R_B/R_g=1000 to date. Initially, our axisymmetric system of constant-density hot gas contains weak vertical magnetic field and rotates in an equatorial plane of a rapidly spinning SMBH. We seed the gas with small-scale 2%-level pressure perturbations. Infalling gas forms an accretion disk, and the SMBH launches relativistically-magnetized collimated jets reaching well outside R_B. Under the pressure of the infalling gas, the jets intermittently turn on and off, erratically wobble, and inflate pairs of cavities in different directions, resembling an X-shaped jet morphology. Synthetic X-ray images reveal multiple pairs of jet-powered shocks and cavities. Large-scale magnetic flux accumulates on the SMBH, becomes dynamically important, and leads to a magnetically arrested disk state. The SMBH accretes at 2% of the Bondi rate (Mdot~2.4e-3 Msun/yr for M87*) and launches twin jets at eta=150% efficiency. These jets are powerful enough (P_jets~2e44 erg/s) to escape along the SMBH spin axis and end the short-lived intermittent jet state whose transient nature can account for the rarity of XRGs.

Mariana Lazarova
University of Northern Colorado
Poster
Mergers Dominate the Host Galaxies of Low-z LoBAL QSOs

The ultrafast outflows characteristic of broad absorption line (BAL) QSOs suggest that, in those systems, we might be observing AGN-driven kinetic feedback capable of affecting the growth of the host galaxy. Particularly relevant to this picture might be low-ionization BAL QSOs (LoBALs) at low redshifts because anecdotal studies find that they might be connected to major mergers and ultra-luminous infrared galaxies. We take a detailed look at the host galaxy morphologies and SEDs of a complete, volume-limited sample of optically-selected LoBALs at 0.5 < z < 0.6. Their infrared luminosities and star formation rates do not suggest they are different from typical type-1 QSOs. After correcting for the AGN contribution to the FIR SED, LoBALs show levels of star formation similar to those of type-1 QSOs. However, the observations of their host galaxies with HST/WFC3 reveal apparent signs of recent or on-going tidal interaction in 68% of the sample, which is in contrast to recent work on QSO hosts showing merger fraction of less than 20-25%. The mergers in our sample represent various stages of the merger process: from double nuclei (41% of the sample) to settled morphologies with extended low surface-brightness tidal tails. If the rarity of BALs is due to the short duration of the outflow phase, then these results might be consistent with theoretical predictions of short-lived, sporadic episodes of AGN activity during various stages of the merger process.

Andrew Lobban
European Space Astronomy Centre Madrid, Spain
Talk
Exploring the Accretion Process Near to a Supermassive Black Hole in Mrk 110 with XMM-Newton, NuSTAR, and Swift

I will present the results of an observing campaign on the nearby, broad-line Seyfert 1 galaxy, Mrk 110, using XMM-Newton, NuSTAR, and Swift. Mrk 110 is an active galactic nucleus with a relatively high supermassive black hole mass of ~10^{8} solar masses. Due to an absence of intervening ionised material in our line-of-sight, we are afforded an unimpeded, direct view of the 'bare' accretion disc as it feeds the central black hole. The high-resolution Reflection Grating Spectrometer on-board XMM-Newton reveals a broad component of the He-like oxygen (O VII) line, which can be modelled with a mildly-relativistic face-on accretion disc profile with the emission arising from very close to the black hole (20-100 gravitational radii). When compared with archival data spanning 16 years, the line also appears variable, and - for the first time - a significant correlation is measured between the O VII flux and the continuum flux from both the RGS and EPIC-pn data. Thus, the line responds to the continuum emission and is one of the clearest examples of such behaviour observed so close to a supermassive black hole to date. As such, this has implications for the accretion mechanism in the closest environs of a black hole. Through simultaneous NuSTAR data, we find that the broad-band X-ray spectrum is dominated by a combination of warm and hot Comptonisation, providing clues to the geometry of the X-ray-producing corona of relativistic electrons close to the black hole. Finally, through a contemporaneous, long-term multiwavelength monitoring campaign with Swift (covering a timeline of three years), we compute long-term rms spectra and use flux-variation-gradient methods to estimate the host-galaxy contribution in the optical and UV bands and independently estimate the bolometric luminosity and mass accretion rate. We also search for multiwavelength time delays, finding a series of lags, whereby longer-wavelength emission bands are systematically delayed with respect to shorter-wavelength bands. We compare these results to others reported in the literature, finding that the observed time delays are longer than predicted, suggesting a larger-than-expected disc. If these time delays arise from reprocessing of X-rays in the accretion disc, this poses challenges for standard accretion theory.

Beverly Lowell
Northwestern University, United States
Talk
Black hole spin gone MAD

Supermassive black holes interact with their host galaxies by accreting gas and expelling energy into the surrounding medium, and relativistic jets are observed in 1 out of every 10 radio galaxies. Since the jets are thought to be powered by black hole spin, radio observations of jets may provide insight to the underlying physics near the black hole. However, it is not understood how black hole spin evolves as black holes grow. We have performed 3D general relativistic hydrodynamic (GRMHD) simulations of magnetically-saturated, or magnetically arrested disk (MAD), accretion onto black holes. We simulated nonradiative and luminous accretion disks representative of sub-Eddington to highly super-Eddington accretion rates, for a wide range of dimensionless black hole spin ($-0.9<a<0.99$). We find that MADs tend to spin down the black holes to low spin values of a ~ 0.1 - 0.5, depending on the Eddington ratio. We construct a semi-analytic model and use it to demonstrate that the low values of equilibrium spin emerge primarily due to the highly sub-Keplerian nature of MADs near the black hole.

Alberto Mangiagli
Laboratoire Astroparticule et Cosmologie (APC), France
talk
Counterpart rates to massive black hole binary mergers in the LISA era

In ~2034 the Laser Interferometer Space Antenna (LISA) will detect the coalescence of massive black hole binaries (MBHBs) from 10^5 to 10^7 solar mass up to z~10. The gravitational wave (GWs) signal is expected to be accompanied by a powerful electromagnetic (EM) counterpart, from radio to X-ray, generated by the gas accreting on the binary.
If LISA locates the MBHB merger within an error box <10 square degree, EM telescopes can be pointed in the same portion of the sky to detect the emission from the last stages of the MBHB orbits or the very onset of the nuclear activity, paving the way to test the nature of gas in a rapidly changing space-time. Moreover, an EM counterpart will allow independent measurements of the source redshift which,

combined with the luminosity distance estimate from the GW signal, will lead to exquisite tests on the expansion of the Universe as well as on the velocity propagation of GWs.
In this talk, I present some recent results on the expected rates of MBHBs counterparts detectable jointly by LISA and EM facilities such as LSST, SKA, ELT and Athena. We combine state-of-the-art models for the galaxy formation and evolution, Bayesian tools to perform the parameter estimation of the GW event and analytical expressions to simulate the EM emission.
We explore three different astrophysical scenarios employing different seed formation (light or heavy seeds) and delay-time models, in order to have realistic predictions on the expected number of events. We estimate the detectability of the sources in terms of its signal-to-noise ratio in LISA and perform parameter estimation, focusing especially on the sky localization of the source. Exploiting the additional information from the astrophysical models, such as the amount of accreted gas and BH spins, we model the expected EM counterpart to the GW signal in soft X-ray, optical and radio.
In our standard scenario, we predict ~ 14 standard sirens (stsi) with detectable counterparts over 4 yr of LISA time mission and ~6 (~20) in the pessimistic (optimistic) one.
For the Athena case, we investigate the trade-off between sky position accuracy and limiting flux: if we increase the sky localization threshold and reduce the limiting flux , the rates decrease by ~20%.
We also explore the impact of absorption from the surrounding gas both for optical and X-ray emission: assuming typical hydrogen and metal column density distribution, we estimate only ~3 stsi in 4 yr in the standard scenario.
Finally we combined the redshift and luminosity distance information to estimate cosmological parameters: we find that H0 can be constrained to ~few percent precision thanks to few sources whose redshift is measured spectroscopically.

Filippo Mannucci
INAF - Arcetri
Talk
Unveiling the missing population of the dual AGNs at sub-arcsec separations

All cosmological models predict the existence of multiple, in-spiraling SMBHs that eventually will merge and give rise to gravitational waves emission. These SMBHs can be revealed as dual AGNS separated by up to a few kpc. Very few such confirmed dual AGNs are currently known, only 2 systems are confirmed at z>1 with separations below 0.8” (~6kpc). Detecting significant numbers of these systems would allow to test one key prediction of the Lambda-CDM hierarchycal models of structure formation and study the physical mechanism driving the inspiralling of the pair of SMBH. Multiple AGNs at small separations can also be due to gravitational lensing, systems of great relevance to many topics of astrophysics.
I will present the novel Gaia Multi Peak (GMP) selection method for dual/lensed AGNs: selecting AGNs showing multiple peaks in the Gaia scans, we identified hundreds of candidates with separations between 0.1" and 0.7". This technique is very efficient: all the selected targets with HST archival images
show two or more point-sources at sub-arcsec separations. One of these systems also have a spatially-resolved spectrum, showing that it contains two distinct SMBHs in the same galaxy.
The observed colors and several tests show that also the majority of the remaining systems are dual/lensed AGNs. I will also present the results of on-going observations with Keck, LBT, and VLT to
study the nature of several such systems.

Michela Mapelli
Department of Physics and Astronomy G. Galilei, University of Padova
Invited review talk
Populations of binary black holes: open questions and challenges

TBD

Paola Marziani
INAF - Astronomical Observatory
Invited review talk
The quasar main sequence and its potential for cosmology

The main sequence offers a method for the systematization of quasar spectral properties. After reviewing some defining trends, we stress how the main sequence contextualization offers a privileged view on several outstanding issues, from the definition of radio loudness to changing-look active galactic nuclei, and to high-redshift distance indicators for cosmology. In this respect, sources with extreme FeII emission at one end of the main sequence are easily identifiable in large spectroscopic surveys over a broad redshift range from their optical and UV spectrum. These extreme quasars — believed to radiate at high Eddington ratio, close to the Eddington limit — turn out to be potential distance indicators, according to a preliminary analysis that provides evidence of the conceptual validity of redshift-independent luminosity estimates based on broad emission line width measures.

Ranjeev Misra
IUCAA, Pune
Talk
Spectral-timing studies of X-ray binaries using AstroSat
TBD

Andrea Melandri
INAF - Brera Astronomical Observatory
Invited review talk
Electromagnetic follow-ups of GW events

The discovery of gravitational waves (GWs) from the coalescence of compact objects is one of the most exciting scientific discoveries of the last decade, and started a "golden age" for the multi-messenger astronomy. Merging of either black hole-neutron star or two neutron stars are among the most promising GW sources able to generate electromagnetic counterparts, but also core-collapsing massive stars and isolated neutron stars could be detected in the near future. Several electro-magnetic counterparts, such as gamma-ray bursts and their afterglows, kilonovae, millisecond pulsars, soft gamma repeaters and core-collapse supernovae, are expected to be associated with these sources. Comprehensive follow-up observational campaigns of GW signals will help to answer to some fundamental questions in astrophysics and physics in general, leading to a more complete understanding of these events. I will review the current status of the observations of GW sources and their EM counterparts and the future perspectives for joint multi-messenger observational campaigns.

Sneha Prakash Mudambi
CHRIST (Deemed to be University), Bangalore Central Campus Bengaluru, India
Talk
AstroSat investigations of spectral and temporal properties of black hole candidate MAXI J1820+070 during the rising phase of its outburst

MAXI J820+070, the brightest X-ray novae discovered till date, was first detected in optical on 6th March by ASSASSN survey and later in X-rays on 11th March 2018 by MAXI/GSC. The follow up multi-wavelength observations revealed that the source is indeed a black hole candidate. Low

inclination angle (~ 30°), proximity of the source (~ 3.46 kpc) and high X-ray flux rate (~10^(-8) erg /cm2/s) provided a unique opportunity to study the physics of accretion and relativistic effects on matter in strong gravity regime with great detail, resulting in observations by almost all leading missions including India's first multi-wavelength astronomical satellite "AstroSat". In this work, we present for the first time the broadband spectral and temporal analysis results using data from SXT and LAXPC onboard AstroSat. AstroSat observed MAXI J1820+070 on 30th and 31st March 2018, during the rising phase of its outburst. The combined SXT and LAXPC spectrum were modelled using thermal Comptonization along with disk blackbody and reflection components. Spectral analysis revealed that the source was in its hard-spectral state ($\Gamma = 1.61$) and with a cool accretion disk (kTin= 0.22) truncated at a large distance. Temporal analysis has revealed frequency-dependent hard lags of the order of 100 ms. Power density spectra showed a presence of a type C quasi-periodic oscillation (QPO) at 47.7 mHz and this is the first confirmed report of such a detection. Additionally, we have modelled the single temperature stochastic propagation model proposed by Maqbool et al., (MNRAS, 486, 2964, 2019) to the observed energy-dependent time-lags and fractional rms and found that the predictions of the model match well with observations. We also compare our findings with that of Cygnus X-1.

Krzysztof Nalewajko
Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences
Invited review talk
Physical processes in jets

Relativistic jets are spectacular collimated outflows that carry a substantial fraction of energy involved in accreting black hole systems. Multiwavelength observations provide evidence for a variety of physical processes operating in jets, and crucially observations put constraints on their efficiencies. I will review the following selected topics relevant for the physics of relativistic jets: (1) launching and powering, (2) acceleration and collimation, (3) stability, (4) energy dissipation, (5) particle acceleration, (6) radiative processes, (7) plasma composition, (8) origin of matter.

Sumana Nandi
Manipal Centre for Natural Sciences. MAHE, India
Talk
A potential binary black hole candidate

Though mergers are natural consequence and common phenomena in the universe, the detection of binary supermassive black holes (SMBHs) with parsec scale separation is not an easy task. The confirmation of binary candidates typically requires multiple signatures as well as multi-wavelength data from different telescopes. To date, the number of confirmed binary SMBHs with tens of pc separations is <10. In our recent study we identified one radio galaxy, J1328+2752, which shows two episodes of jet activity with axis rotation. The double-peaked lines in its optical spectrum indicating a binary black hole at a separation of ~ 6 pc. We explored the feasibility of such phenomenon using a pure kinematic precession model. The precession helices generated by the model match well with GMRT and VLA data. This model indicates that the jet precession in J1328+275 may be induced by the torques in the primary accretion disk due to the secondary black hole in a non-coplanar orbit around the primary one. Further we have carried out VLBI imaging of this source. VLBI image reveals two radio cores with brightness temperatures of ~ 10^7 K . Moreover, the estimated binary separation obtained from the double-peaked lines matched exactly with the VLBI data. Here we discuss different possible signatures of a central binary black hole in this unique radio galaxy.

Andrzej Niedzwiecki
University of Lodz, Poland
Invited review talk
Constraining accretion flows with X-ray spectral data

I present GR models of spectral formation in both optically thin as well as optically thick black-hole accretion flows and their application to selected black hole systems accreting at low, moderate and high accretion rates.

Maxwell Paik
Northwestern University
Talk
Simulations of relativistic jets breaking out of their galaxies

As supermassive black holes (SMBHs) accrete ambient gas, they can launch highly magnetized, relativistic outflows known as jets. These jets represent some of the most powerful, fast-moving structures in the universe, with energies vastly exceeding the binding energy of their host galaxy. As they propagate away from the SMBH, they run into the ambient medium. This can significantly affect the jet's shape, angular structure, and composition: the jets recollimate, form backflows, and develop internal magnetic instabilities and dissipation. Observations indicate that as jets run into the ambient medium they typically undergo transition from a parabolic shape to a conical one and display stationary energetic features. Jet structure also changes once the jets escape out of the ambient medium, i.e., exit the galaxy: the backflows no longer form, and the jets transition into a conical shape, entering a free-expansion regime where the jets can effectively accelerate.
To reveal the physics behind these transitions and the jet-ambient medium interaction, I employ 3D general-relativistic magnetohydrodynamic (GRMHD) simulations. I initialize them with a magnetized torus placed inside a static ambient medium. Accreting gas launches a pair of jets that drill their way out through the ambient medium. To reveal the effect the ambient medium has on the jets, I consider three ambient medium configurations: one where the surrounding medium extends out to infinity, one where the ambient medium extends out to a finite distance, and one without any ambient medium. I will present the resulting jet-shape profiles as a function of distance from the SMBH and the angular distribution profiles of jet power, velocity, and magnetization, making comparisons to observations.

Eliana Palazzi, A. Rossi, et al.
INAF/OAS Bologna
Poster
The peculiar short-duration GRB 200826A and its supernova

Gamma-ray bursts (GRBs) are classified as long and short events. Long GRBs (LGRBs) are associated with the end states of very massive stars, while short GRBs (SGRBs) are linked to the merger of compact objects.GRB 200826A was a peculiar event, because by definition it was a SGRB, with a rest-frame duration of$\sim$0.5 s. However, this event was energetic and soft, which is consistent with LGRBs. The relatively low redshift (z = 0.7486) motivated a comprehensive, multi-wavelength follow-up campaign to characterize its host, search for a possible associated supernova (SN), and thus understand the origin of this burst. To this aim we obtained a combination of deep near-infrared (NIR) and optical imaging together with spectroscopy. Our analysis reveal an optical and NIR bump in the light curve whose luminosity and evolution is in agreement with several LGRB-SNe. Analysis of the prompt GRB shows that this event follows the Ep,i − Eiso relation found for LGRBs. The host galaxy is a low-mass star-forming galaxy, typical for LGRBs, but with one of the highest star-formation rates (SFR), especially with respect to its mass (log M∗/M = 8.6, SFR $\sim$4.0 M /yr). We conclude that GRB200826A is a typical collapsar event in the low tail of the

duration distribution of LGRBs. These findings support theoretical predictions that events produced by collapsars can be as short as 0.5 s in the host frame and further confirm that duration alone is not an efficient discriminator for the progenitor class of a GRB.

Olmo Piana
National Taiwan Normal University
Talk
The mass assembly of the high-redshift black hole population

We apply the semi-analytic model of galaxy formation and evolution Delphi to the study of the growth of the high-redshift black hole population across its full mass range, in order to provide its physical characterisation as a function of mass and redshift. The model, based on analytical merger trees, consistently follows the emergence of galaxies and black holes from z=20 to z=4, accounting for dark matter and gas accretion onto the galaxy, star formation, black hole growth and feedback from both supernovae and AGN activity. Motivated by the results of several numerical simulations, our black hole growth implementation introduces a critical halo mass below which the black hole is starved. The free parameters of the model are tuned to reproduce the main galaxy and black hole statistical observables at z > 4. We analyse the mass assembly history of central black holes along the merger trees as a function of halo mass, studying also the contribution of the AGN population to the total UV luminosity function, and the impact of AGN feedback on the stellar mass assembly.

Tsvi Piran
The Hebrew University, Jerusalem, Israel
Invited review talk
The theory of stellar tidal disruption events (TDEs)
TBD

Mathieu Renzo
CCA, Flatiron Institute, USA
Talk
Progenitors of the most massive BHs: where is the PISN gap?

The gravitational wave detections to date challenge the predicted lack of black holes in the ~60-130 M_{\odot} range because of pair-instability supernovae (with updated nuclear physics). While the theoretical models of single core explosions seem robust, many open questions in the progenitor life remain. I will briefly review ideas on the formation of "forbidden" stellar mass black holes (dynamical assembly, modified stellar evolution, AGNs), and focus two specific stellar evolution mechanisms: "wet merger" of stars creating non-canonical pre-explosion cores, and rotationally-driven explosion filling the gap "from above". The "wet merger" scenario faces some stellar evolution challenges, which can be further investigated leveraging large spectroscopic surveys and transient surveys. Similarly, models filling
the gap "from above" require extrapolating explosion engine models to extremely massive progenitors, but the predictions for the "super-kilonova" electromagnetic transient accompanying these events will soon be constrained by the Roman space telescope.

Valeriia Rohoza
Northwestern University
Talk
How to turn jets into cylinders near supermassive black holes in 3D GRMHD simulations

Accreting supermassive black holes (SMBHs) produce highly-magnetized relativistic jets that tend to gradually collimate as they fly away from their SMBHs. However, recent radio interferometric observations of the relativistic jets in the 3C84 galaxy have revealed a stunning, cylindrical jet very close – within hundreds of Schwarzschild radii – to the black hole! To explore how such extreme collimation comes to be, we use 3D general-relativistic magnetohydrodynamic (GRMHD). For this, I consider a SMBH surrounded by a magnetized torus immersed into a constant-density ambient medium. I demonstrate that the jet-ambient medium interactions produce backflows, which – alongside the disk winds – provide the necessary lateral pressure support to collimate the jets into cylinders. However, this collimation happens at much larger distances than observed in 3C84. I will then demonstrate that radiative disk cooling, which is inferred to take place in 3C84, reduces the distance at which the jets turn into cylinders and brings it into an agreement with the observations. I will discuss how cooling affects the mass-accretion rate, jet power, lateral jet power, and velocity distributions.

Dorota Rosinska
University of Warsaw, Poland
Invited review talk
The discovery of gravitational waves, and merging and colliding black holes from globular clusters as sources of GWs

Stellar mass binary black holes are the most important sources of gravitational waves for ground based interferometric detectors. The discovery of GWs is first reviewed. Then, merging and colliding black holes from globular clusters as sources of GWs are discussed.
We analyze about a thousand globular cluster (GC) models simulated using the MOCCA Monte Carlo code for star cluster evolution to study black hole - black hole interactions in these dense stellar systems that can lead to gravitational wave emission. We extracted information for all coalescing binary black holes (BBHs) that merge via gravitational radiation from these GC models and for those BHs that collide due to 2-body, 3-body and 4-body dynamical interactions. By obtaining results from a substantial number of realistic star clusters evolution model, that cover different initial parameters (masses, metallicities, densities etc) we have an extremely large statistical sample of two black holes which merge or collide within a Hubble time. The existence of Intermediate Mass Black Hole strongly influences the results. I will discuss the importance of merging and colliding black holes originating from GC for gravitational waves observations.

Rupak Roy
MCNS, MAHE, India
Talk
Are all classified TDEs indeed stellar-disruption by SMBH?

With the advent of the time-domain astronomy brilliant transients have been discovered near the centers of the galaxies. Most of them are brighter than canonical supernovae and exhibit very broad lightcurves with almost featureless spectra at early stages, and spatially unresolved from the host centers. Rapid spectroscopic follow-ups of these objects by transient surveys like ePESSTO, ZTF, ASASSN have shown that spectral evolutions of these objects are different from that of supernovae, and their temporal evolutions can be explained to some extent as stellar-disruption events due to the tidal force of the supermassive blackhole (SMBH) at the center of the host. However, the complete picture of the disruption-geometry is yet not well known. Also, the spectral classifications of these tidal disruption events (TDEs) are yet incomplete. Moreover, recently several nuclear-transients, with ambiguous spectral and temporal evolution, have been discovered. The characteristics of these ambiguous nuclear events are neither like canonical TDEs nor like regular AGNs. Here, I will summarize the characteristics of some of these events which have been followed by us using facilities throughout the world. I will also discuss about the probable progenitors and explosion geometries of these explosions.

Taeho Ryu
The Max Planck Institute for Astrophysics, Germany
Talk
Fully relativistic global hydrodynamics simulation of tidal disruption events

Approximately 100 tidal disruption event candidates have been observed. In the near future, the number will grow dramatically with detections by the ongoing and upcoming surveys (e.g., eROSITA and LSST). However, the mechanism responsible for the luminosity and the shape of the light curve of observed events is poorly understood. For reliably classifying transients and deciphering their emission features to unveil the nature of the main source and surroundings, it is crucial to understand the dominant emission mechanisms of the events. The only way to fully investigate the long-term evolution of the debris and the emission mechanism is to perform global simulations with astrophysically realistic initial conditions. However, performing such simulations had been considered almost impossible because of very high computational costs. Using an innovative numerical technique that I have developed, we are currently performing a fully relativistic global hydrodynamics simulation of a main-sequence star with realistic initial conditions and investigating the emission mechanism. I will present the results from our simulation and discuss their implications.

Kailash Sahu
Space Telescope Science Institute
Talk
Detection and Mass Measurement of the First Isolated Stellar-Mass Black Hole Through Astrometric Microlensing

We describe the first unambiguous detection and mass measurement of an isolated stellar-mass black hole (BH). We used the Hubble Space Telescope (HST) to carry out precise astrometry of the source star of the long-duration (T ~ 270 days), high-magnification microlensing event MOA-2011-BLG-191, in the direction of the Galactic bulge. HST imaging, conducted at eight epochs over an interval of six years, reveals a clear relativistic astrometric deflection of the background star's apparent position. Ground-based photometry shows a parallactic signature of the effect of the Earth's motion on the microlensing light curve.
Combining the HST astrometry with the ground-based light curve and the derived parallax, we obtain a lens mass of 7.1 +/- 1.3 solar mass and a distance of 1.58 +/- 0.18 kpc.
We show that the lens emits no detectable light, which, along with having a mass higher than is possible for a white dwarf or neutron star, confirms its BH nature. Our analysis also provides an absolute proper motion for the BH. The proper motion is offset from the mean motion of Galactic-disk stars at similar distances by an amount corresponding to a transverse space velocity of ~45 km/s, suggesting that the BH received a modest natal "kick'' from its supernova explosion. Previous mass determinations for stellar-mass BHs have come from radial-velocity measurements of Galactic X-ray binaries, and from gravitational radiation emitted by merging BHs in binary systems in external galaxies. Our mass measurement is the first ever for an isolated stellar-mass BH using any technique.

Payaswini Saikia
New York University Abu Dhabi, United Arab Emirates
Talk
Seven re-flares and two mini-outbursts : high amplitude optical variations in Swift J1910.2-0546

Black hole X-ray binaries (BHXBs) provide the easiest means to study stellar-mass black holes. Outbursts of BHXBs typically last months-years and are quite often characterized by a fast-rise, exponential decay light curve profile. However there are many exceptions, with some sources rising slowly, some having multiple

peaks, and some displaying flares, dips, plateaus and re-brightenings. While re-flares during outburst decays are fairly common, re-brightenings after the end of the outbursts, when the source has reached quiescence, have been reported in far fewer BHXB sources. The origin of re-flares and mini-outbursts are a matter of debate, but can be a powerful tool to either strengthen or challenge the disk-instability model (which predicts that outbursts are regulated by thermal-viscous instabilities in the accretion disk), and help us understand the outburst cycles in BHXBs.
We present long-term optical monitoring of the black hole candidate X-ray binary Swift J1910.2-0546 with the Faulkes Telescopes, including the historic outburst in 2012 and the recent mini-outburst in February 2022. We also report two periods of re-brightening activities previously undocumented in the literature. We find that following the 2012 outburst, the source has displayed a series of at least seven quasi-periodic, high amplitude optical re-flares in 2013, with a recurrence time increasing from ∼42 days to ∼49 days. This was followed by a mini-outburst with two peaks in 2014. The flaring behavior during both the re-brightening periods show a bluer when brighter behavior, having optical colors consistent with a blackbody heating and cooling between 4500 and 9500 K, the temperature range in which hydrogen ionizes. We compare the flaring behavior of the source with re-brightening events observed in other BHXBs within one year of an outburst. We discuss the different scenarios which could cause such extreme flaring, and propose that the highly unusual repeated flaring in Swift J1910.2-0546 can arise from a sequence of heating and cooling front reflections in the accretion disk following the disk instability model, probably due to the presence of a hot inner disk at the end of the main outburst.

Om Sharan Salafia
Università degli Studi di Milano-Bicocca
Invited review talk
GRBs from binary mergers

The connection between gamma-ray bursts (GRBs) and compact binary mergers was foreseen as early as the late 80's by Packzynski and Eichler. Ironically, the association between FRB980425 and SN1998bw clearly favoured the alternative scenario of a collapsar progenitor for at least some gamma-ray bursts.
Despite the mounting circumstantial evidence in favour of the connection between compact binary mergers and GRBs of the short/hard class, the final (and spectacular) confirmation only came on the 17th of August 2017 with GW170817 and GRB170817A. I will review what we have learnt from this single extraordinary event in terms of new insights about the physics of the jet formation and launching, its interaction with the other merger ejecta, the processes behind the prompt and afterglow emission and the structure of the shock that produces the afterglow. I will then critically discuss the possibility and relevance of other binary mergers as progenitors of gamma-ray bursts.

Andrea Sanna
University of Cagliari
Talk
On the peculiar long-term orbital evolution of the eclipsing accreting millisecond X-ray pulsar SWIFT J1749.4-2807

SWIFT J1749.4-2807 is the only Accreting Millisecond X-ray Pulsar (AMXP) showing both pulsations and eclipses from its X-ray emission among the 22 systems currently known. This peculiar source has been observed in outburst for the first time in 2010, and after almost eleven years of quiescence state, it has been recently detected again in outburst. Combined pulse and eclipse timing solution allowed to set tight constraints on the orbital parameters and inclination (74-77 degrees) of the system, which implies a companion mass ranging between 0.6 and 0.8 solar masses for a likely range of neutron star masses. Here I present the timing analysis of SWIFT J1749.4-2807 using NICER and XMM-Newton data collected during its latest outburst. From the timing analysis of the pulse phase delays, we obtained an updated set of orbital parameters that we compared with those of the previous outburst to investigate its long-term evolution. I will then focus on the fast expansion of both the NS projected semi-major axis, and the orbital period obtained from the analysis to constrain its secular evolution and further investigate possible scenarios compatible with these results.

Andrea Santangelo
University of Tübingen, Germany
Invited review talk
Science highlights from Insight-HXMT

In this contribution I will review the main results of the Insight-HXMT mission in studies of compact objects, focusing on black holes.

Andrea Santangelo
University of Tübingen
Talk
The enhanced X-ray Timing and Polarimetry mission (eXTP)

I will present the science case, the payload and the current status of the eXTP mission that is designed to study the state of matter under extreme conditions of density, gravity and magnetism.

Nina Sartorio
University of Cambridge, UK
Talk
The first accreting Black Holes

The first population of X-ray binaries are expected to affect the thermal and ionization states of the gas in the early Universe. Although these X-ray sources are predicted to have important implications for high-redshift observable signals, such as the hydrogen 21-cm signal from cosmic dawn and the cosmic X-ray background (CXB), their properties are poorly explored, and theoretical models are lacking detail.
In this talk I will present the first models of a population of X-ray binaries arising from zero metallicity (Pop III stars) stars. I will explore how properties of the first X-ray binaries depend on the adopted initial mass function (IMF) of primordial stars and the implications this has for the early evolution of the Universe.
In addition, I will show that, depending on the adopted IMF and on whether pair-instability supernovae are included, the contribution of these binaries to the unresolved CXB would be incompatible with observed values. As such, we can constrain the IMF of Pop III stars as well as present compelling evidence for the existence of pair-instability supernovae. Lastly, I will show how our models can provide scaling relations between XRBs and their X-ray feedback with the local star formation rate, which can then be used in sub-grid models to improve the X-ray feedback prescriptions.

Nial Tanvir
University of Leicester
Invited review talk
The Transient High-Energy Sky and Early Universe Surveyor (THESEUS)

The Transient High-Energy Sky and Early Universe Surveyor (THESEUS) is a space mission concept under continuous development by a large international collaboration and studied by ESA in 2018-2021 as candidate M5 mission. THESEUS aims to exploit Gamma-Ray Bursts for investigating the early Universe and to provide a substantial advancement of multi-messenger and time-domain astrophysics. Through an unprecedented combination of X-/gamma-rays monitors, an on-board IR telescope and automated fast slewing capabilities, THESEUS will be a wonderful machine for the detection, characterization and redshift measurement of any kind of GRBs and many classes of X-ray transients. In addition to the full exploitation of high-redshift GRBs for cosmology (pop-III stars, cosmic reionization, SFR and metallicity evolution up to the "cosmic dawn"), THESEUS will allow the identification and study of the electromagnetic counterparts to sources of gravitational waves which will be routinely detected in the 2030s by next generation facilities like aLIGO/aVirgo/KAGRA/LIGO-India, and Cosmic Explorer/Einstein Telescope (ET), as well as LISA. In particular, THESEUS will detect, localize and measure the redshifts for tens/year of EM counterparts (short GRBs, soft X-ray emission, kilonova emission) to GW signals coming from NS-NS and NS-BH mergers, and possibly other GW sources, detected by ET, thus providing unique clues to the physics and progenitors of these phenomena and allow their full exploitation for fundamental physics and cosmology. Finally, Theseus will detect many other classes of high-energy transient sources, thus providing an ideal synergy with the large EM facilities of the near future like LSST, ELT, TMT, SKA, CTA, ATHENA.

Justine Tarrant
University of the Witwatersrand, South Africa
Poster
Studying patched spacetimes for binary black holes

Circumbinary accretion disks have been examined, theoretically, for supermassive and intermediate mass black holes, however, disks for black hole masses in the LIGO regime are poorly understood. Assuming these binaries possess such a disk initially, the question we want to answer is: are they dissipated by outflows or accretion prior to inspiral? To study this problem we propose a novel approach, whereby we consider an approximate, analytic spacetime and solve the geodesic equation for particles in this spacetime so that we can determine the likely fate of particles coming from the accretion disk. Preliminary indications suggest a likelihood of accretion prior to inspiral.

Victoria Toptun
Sternberg Astronomical Institute, Russia
Talk
Expanding a bona fide sample of intermediate-mass black holes in active galactic nuclei: X-ray confirmation of thirteen candidates with XMM-Newton and Chandra

Intermediate mass black holes play a key role in our understanding of SMBH formation and growth. But the current bona-fide sample of IMBH candidate comprises only 10 objects, where the AGN nature was confirmed by direct X-Ray observations. Here we present a confirmation of additional 13 IMBHs from a sample of 305 optically selected candidates by Chilingarian et al. (2018). Six of them were confirmed with our own XMM-Newton EPIC observations. Another five were identified in the recent release of the XMM source catalog 4XMM DR9 and one from Chandra CSC2. Also added two from XMM archival data and nine from Chandra archival data. With the expanded sample of bona fide IMBHs we probe BH accretion rates in low-mass AGN and identify two galaxies close to the Eddington limit.

Devendra Raj Upadhyay
Department of Physics, Amrit Campus, Tribhuavan University, Nepal
Overview talk
Status of Astrophysics in Nepal

The current work presents a review of research work and activities related to astrophysics in Nepal. Although researchers are interested in diverse fields such as the interstellar medium, black holes, galaxy orientation, and the formation of astrophysics in Nepal, due to limited resources of well-trained manpower in this field and fewer facilities for observational astronomy, our students and researchers are working on theoretical aspects only, and it is difficult to make astrophysics as subjective as it should be. From this review, we have concluded that student exchange programs from our university to high-standard research institutions are needed to strengthen the level of observational and cutting-edge astrophysics research in Nepal.

E. Virgilli, F. Frontera, P. Rosati, C. Guidorzi, L. Ferro, M. Moita, E. Palazzi, L. Amati, N. Auricchio, L. Bassani, R. Campana, E. Caroli, F. Fuschino, C. Labanti, M. Orlandini, J.B. Stephen, S. Del Sordo, C. Ferrari, R. Lolli on behalf of an international collaboration

Poster

The ASTENA mission: bringing the hard X-ray/soft gamma-ray sky into focus

Hard X-/soft Gamma-ray astronomy is a key field for understanding the transient sky and for nuclear astrophysics. However, the sensitivity of the measurements is, above 70 keV, strongly limited by the use of direct view instrumentation. To overcome this limitation, a mission currently under study called ASTENA (Advanced Surveyor of Transient Events and Nuclear Astrophysics) has been proposed in the context of the AHEAD Horizon 2020 program and discussed in two white papers (Frontera et al. (2021) - Exp.Astr. Vol. 51, Issue 3, p.1175-120, Guidorzi et al. (2021) - Exp.Astr. Vol. 51, Issue 3, p.1203-1223) submitted to ESA for the “Voyage 2050” call. ASTENA consists of two complementary instruments: an array of wide-field monitors with imaging, spectroscopic, and polarimetric capabilities in the 2 keV–20 MeV passband (WFM-IS) and a Narrow Field Telescope (NFT) based on a Laue lens, operating in the 50-600 keV range, with un unprecedented angular resolution, polarimetric capabilities, and sensitivity. We also propose a pathfinder of ASTENA, that will be submitted to ASI as an Italian medium class mission within an international collaboration.

Pavan Vynatheya
Max Planck Institute for Astrophysics

Talk

Gravitational waves from quadruple stars - quadruple the fun! (?)

Mergers of black holes (BHs) and neutron stars (NSs) result in the emission of gravitational waves that can be detected by LIGO. We look at 2+2 and 3+1 quadruple-star systems, which are common among massive stars, the progenitors of BHs and NSs. We carry out a detailed population synthesis of quadruple systems using the Multiple Stellar Evolution code, which seamlessly takes into consideration stellar evolution, binary and tertiary interactions, N-body dynamics, and secular evolution. We find that, although secular evolution plays a role in compact object (BH and NS) mergers, (70-85)% (depending on the model assumptions) of the mergers are solely due to common envelope evolution. The BH-BH merger rates represent a significant fraction of the current LIGO rates, whereas the other merger rates fall short of LIGO estimates.

Martin Ward
Durham University, United Kingdom

Invited review talk

Progress towards a better understanding of "Changing Look" AGN

The terminology "Changing Look AGN" as applied to optical spectroscopy is approaching its first decade. It is now quite clear that the classification encompasses a heterogenous group of AGN .The term "Changing Look" is probably now ingrained in astronomy, but a better description would be "Changing State", as this is not specific to the observational

window. We have embarked on several observational studies which include tracking examples of variable objects found from satellite alerts, in addition to mining databases such as those of XMM-Newton and Swift. We have used follow-up spectroscopy and long term lightcurves to define subgroups, and hence separate supernova events, TDE's and those genuine changing look AGN.
I will describe our results in terms of the underlying physics of accretion phenomena, possible jets, and variable obscuration. This information will be very relevant to forthcoming "Big Data" samples of

Andrzej Zdziarski
N. Copernicus Astronomical Center, Poland
Talk
Accretion flow, pair production and jet in the black-hole X-ray binary MAXI J1820+070

I will discuss a number of results on the hard spectral state of accreting black-hole binary MAXI J1820+070 (Zdziarski et al., 2021a, b, ApJL, 2022a, b, ApJ). We analyze X-ray spectra from NuSTAR and Insight-HXMT and find the accretion disc is truncated at more than 10 gravitational radii. The X-rays and soft gamma rays are emitted by a two-component hot accretion flow surrounding the disc via Comptonization. These spectral results are supported by timing analyses of De Marco et al. 2021 and Dzielak et al. 2021. Thanks to simultaneous spectra from INTEGRAL, we find the electron distribution is hybrid, i.e, predominantly thermal but with a significant non-thermal tail. The spectra are measured up to about 2 MeV, which allows us to accurately measure the electron-positron pair production rate. We find the pair abundance within the hot flow is low, which is supported by the lack of a measurable annihilation feature. However, the gamma rays also produce pairs in the magnetically-dominated base of the jet, which, as follows from the contemporaneous radio-to-optical data, can then provide most of the synchrotron-emitting electrons upstream in the jet. Finally, by comparing the jet and accretion emission we find the hot flow can be magnetically arrested.

Janusz Ziolkowski
Copernicus Astronomical Center
Talk
The Donor of the Black-Hole X-Ray Binary MAXI J1820+070

MAXI J1820+070 is the first X-ray binary for which there is a strong observational evidence of a substantial misalignment between the axis of the black hole spin and the axis of the orbital angular momentum. This fact has important consequences for the determination of the masses of the black hole and its binary companion. We estimate the parameters of the donor in the system without making the alignment assumption. We find that observational data indicate that donor is a subgiant with the radius in the range 1.11 to 1.26 $R_{\odot}$ and the effective temperature greater than 4200 K. We perform evolutionary calculations for the binary system and compare them to the observational constraints. For the distance to the system equal 3 kpc (as favoured by both the radio and the Gaia parallax) our preferable model of the donor has the mass 0.4 M_sun, T ≈ 4200 K and solar metallicity. For the (less likely) distance of 3.3-3.4 kpc our alternative models have either the mass 0.4 M_sun, T ≈ 4500 K and half solar metallicity or the mass 0.5 M_sun, T ≈ 4300 K and solar metallicity. The model predicts the mass transfer rates of 10-10 M_sun/yr, compatible with the observational estimates based on the mass of ≈ 2 x1025 g accreted during the 2018 outburst and the 84 yr interval between the last two outburst.

Posters from local participants:

Dinesh Bishwakarma
Kathmandu University, Bhaktapur, Nepal
Poster
Detection of Quasiperiodic Oscillation in X-ray Lightcurve of Blazar MRK 501 using Swift/XRT

We aim to detect the quasiperiodic oscillations (QPOs) in the X-ray light curve of blazar MRK 501. Any quasi-periodic variations discovered in the blazar lightcurves would contain vital information on the location and the nature of process within the emission region. The source was observed with Swift-XRT telescope, and the data was analyzed by downloading from the Swift-XRT master catalog. We applied the Lomb-Scargle periodogram and epoch folding method for the possible detection of the quasiperiodic oscillations in the source MRK 501. Approximately 15 years of data were analyzed and we detected the quasiperiodic oscillations of 397 days with uncertainty of ±4days (FWHM). As possible explanations for existence of QPOs in the in the X-ray lightcurve, we discuss a number of scenarios, including binary supermassive blackhole system, Lens-Thirring and jet precession.

Ashok Chaudhary
Tribhuvan University, Nepal
Poster
Distribution of Dust Color Temperature, Planck's Function, Dust Mass, and visual extinction around PSR J1240-4124

The physical properties of the cavity around the pulsar PSR J1240-4124 have been studied in IRIS and AKARI survey. The dust color temperature in the IRIS survey is found to be in the range of 23.607 ± 0.012 K to 24.342 ± 0.012 K with an offset of 0.735 K. In the case of the AKARI survey, the dust temperature was found to be in the range of 16.123 ±0.017 K to 18.802 ± 0.017 K with an offset of 2.679 K. The average dust mass in IRIS survey is found to be 2.1 × 10−4 M and that of the AKARI is 8.1× 10−4 M . The size of the structure in the IRIS map is 14.62 pc × 6.24 pc and that of the AKARI map is 5.80 pc × 0.17 pc. The angle of inclination for the selected cavity region is found to be 73.330◦ in IRIS and that of AKARI is 110.260◦. The average visual extinction in the IRIS and the AKARI maps are found to be 1.49 × 10−4 mag and 5.81× 10−4 mag respectively. We have tried to present the relationship among the different physical parameters and compare the results in the IRIS and the AKARI surveys.

Amar Raj Ghimire
Patan Multiple Campus,Tribhuvan University, Nepal
Poster
Study of Relative Abundances of Gas-Rich Galaxies to constrain the Early Nucleosynthesis Model

In this existence every visible particle is associated with electromagnetic wave. Either they absorb or they emit radiation .While the radiations coming from quasars interacts with medium in the observation line, the electromagnetic properties of medium is encoded in the corresponding radiations. With the help of telescope data we decode the absorption and emission features and find the chemical composition of the medium. In this way finding the chemical composition of early universe will lead us to the history of very beginning. In this research we took the quasar absorber systems,from Solon Digital Sky Survey (SDSS) Data Release 17 , of Hydrogen column densities of log_N 〖N_HI ≥〗20.3 which are assumed to be rich in neutral gas for early star formation in the high red shift(3≤Z≤5) universe. Absorption features of first ionization stage of O and second ionization stage of C II , Si II , FeII , Mg II , S II ,Zn II , Al II are observed to calculate the column density and so metallicity and relative abundances Si/O ,Fe/O ,C/O ,and Si/C . Cosmic chemical evolution models predict the mean metallicity of galaxies to rise from low metallicities at high ~Z to a near-solar level at Z ~ 0 .In this research some ionized gas rich absorber are found but of low metallicity and some are of higher metallicity . The early evidence for metal rich absorber are discussed with the help of relative abundances. Finally we tried to constrain the Nucleosynthesis model.

Madhu Paudel
Department of Physics, Tri-Chandra Multiple Campus, Tribhuvan University, Nepal
Poster
Studies of Dust Properties in Sub-Structures around White Dwarf WD 0307+077 in IRIS Survey

A huge dust structure of size 3$^{\circ}\times3^{\circ}$ consisting of many sub-structures of dust nebulae and dust cavities is discovered around the WD 0307+077, located at RA (ICRS): 47.59°, DEC:+7.84°, in far-infrared wavelength of IRIS survey. The sub-structure is divided into five isolated dust nebulae (N1, N2, N3, N4 and N5) and two cavities (C1 and C2). Infrared flux density from each pixels of 60 μm and 100 μm FITS image are extracted using Aladin v11.0. The dust color temperature and dust mass are calculated in each pixels of all sub$-$structures. The contour plot is used to visualize the variation of infrared flux, dust color temperature and dust mass within all sub$-$structures. The inclination angle of isolated region of sub$-$structures is calculated to know the shape of the dust cloud. It is found that the dust color temperature of all the nebulae and cavities are lies between the 20 K to 24 K, with range not more than 3 K. This much range of temperature suggests that the sub$-$structures are moving towards the thermal stability. The dust mass shows the similar mass composition within all sub$-$structures, with variation of just one order magnitude. The linear regression shows a very good linear relation between between the infrared flux at 60 μm and 100 μm wavelength with regression coefficient more than 0.90 in five sub$-$structures and more than 0.78 in remaining two. The inclination angle of shows the all sub$-$structures are clearly \textit{edge$-$on} in shape having inclination angle $i>45^{\circ}$. A study of background sources shows a huge number of SIMBAD sources within the dust structure, which consists of the various type of star and ISM components. The Gaussian distribution of dust color temperature in all sub$-$structures shows more or less deviation from Normal distribution, the background sources observed in the SIMBAD database are suspected for this deviation.

Anil Subedi
Amrit Campus, Tribhuvan University, Nepal
Poster
DISTRIBUTION OF DUST PROPERTIES AROUND NGC 7023 NEBULA IN INTERSTELLAR MEDIUM USING IRIS, AKARI AND WISE SURVEY

In this dissertation, we have studied the physical properties of the strong cavity around the nebula NGC 7023. The physical properties have been studied at 60 µm and 100 µm in the IRIS survey, 90 µm and 140 µm in the AKARI survey, and 12 µm and 22 µm in the WISE survey at right ascension (R.A.) (J2000) = 21h 01m 35.60s , declination (J2000) = + 68◦ 10m 10.0s. Physical properties such as dust color temperature, Planck's function, dust mass, and visual extinction at a distance of 335.82 pc were investigated. With a systematic search of a NGC 7023, we found the dust color temperature is in the range between 36.19 K ± 0.034 K to 24.49 K ± 0.034 K with an average dust color temperature 28.24 K ± 0.034 K in IRIS survey and range between 38.80 K ± 0.251K to21.00 K ± 0.251 K with an average dust color temperature 26.39 K ± 0.251 K in AKARI survey. Similarly in WISE, the dust color temperature found in the range between 130.92 K ± 0.009 K to 88.71 K ± 0.009 K with an average 104.76 K ± 0.251 K.The temperature in WISE is higher than that of the IRIS and AKARI surveys, as it has an inverse relationship with flux. We also calculated the dust mass whose average value was found to be 1.18 × 1027 kg (5.93 × 10−4 M⊙)in IRIS, 1.06 × 1028 kg (5.33 × 10−3M⊙) in AKARI, and 1.06 × 1027 kg (5.33 × 10−4 M⊙) in the WISE survey. We have studied the variation of dust color temperature along with visual extinction and is found to be in the range of 1.83 × 10−12 mag. to 2.23 × 10−13 mag. with an average value 6.46 × 10−13 mag. in IRIS, 1.45 × 10−11 mag. to 1.09 × 10−12 mag. With an average value 5.78 × 10−12 mag. in AKARI and 2.39 × 10−13 mag to 1.17 × 10−14 mag. with an average value 5.31 × 10−14 mag. in WISE. It is concluded that the inverse relation between extinction and temperature. We have also studied the distribution of dust color temperature, which is normal fit with positive skewness. This work will contribute to the understanding of infrared band emission from the dusty region around nebular structure in the interstellar medium.

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