IAUS 324:

New Frontiers in Black Hole Astrophysics

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Book of Abstracts

Edited by Andreja Gomboc

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Public Lecture

Gravitational waves: A new astronomy

Sheila Rowan

Institute for Gravitational Research,
University of Glasgow, UK

20:00-21:00, September 14$^{\text{th}}$, 2016

Ripples in the curvature of space-time - 'gravitational waves' - are produced by some of the most energetic and dramatic phenomena in our universe, including black holes, neutron stars and supernovae.

Close to 100 years after the prediction of the existence of gravitational waves, the advanced detectors of the Laser Interferometer Gravitational-wave Observatory (LIGO) detected such signals for the first time, starting a new era in astronomy. This talk will explain the nature of gravitational waves, describe what sources out in the Universe can produce them, explain how they are detected and what the future of this new era in astronomy might look (and sound) like.

Abstracts

Topic 1: Similarity and diversity of black hole systems

First Frontiers in Black Hole Astrophysics

12 Sep
9:05
Invited

Virginia Trimble

Univity of California Irvine & Queen Jadwiga Observatory, USA

The year 2016 sees a number of significant anniversaries in black hole astrophysics. The centenary of the Schwarzschild solution, with Michell's similar idea 230 years old and Kerr black holes celebrating their 53rd birthdays join the first 50-year-old plausible design for a gravitational radiation detector. Remarkable progress was made in General Relativity in the years 1916-1918 (Lense, Thirring, Reisner, Nordstrom, and others) despite the ongoing Great War. And even an unrecognized GRB hit a nuclear test monitor 50 years ago. SNR 1987A is one year shy of its 30th natal day (arrival of the photons here, of course, not their departure from the NS!). The supernova remnant must know whether there is a neutron star, a black hole, or neither at its center, but we do not. A good many of these items are "history" from the point of view of younger participants, but, for better or for worse, "current events" to my generation.

Similarity and diversity of black holes - view from the Very High Energies

12 Sep
9:45
Invited

Elina Lindfors

Tuorla Observatory, Department of Physics and Astronomy, University of Turku, Finland

Active galactic nuclei, hosting supermassive black holes and launching relativistic jets, are the most numerous objects on the gamma-ray sky. At the other end of the mass scale, phenomena related to stellar mass black holes, in particular gamma-ray bursts and microquasars, are also seen on the gamma-ray sky. While all of them are thought to launch relativistic jets, the diversity even within each of these classes is enormous. In my review, I will show recent gamma-ray results that underline both the similarity of the black hole systems in these scales, as well as their diversity.

Astrophysics of black hole powered jets

12 Sep
10:15
Invited

Alexander Tchekhovskoy
University of California, Berkeley, USA

I will review the theory of jet production across a variety of astrophysical systems, such as active galactic nuclei, tidal disruption events, and gamma-ray bursts.

Causal production of the electromagnetic energy flux and role of the negative energies in Blandford-Znajek process

12 Sep
11:05
Contributed

Kenji Toma[1] and Fumio Takahara[2]
[1]Tohoku University, Japan; [2]Osaka University, Japan

Blandford-Znajek process, the steady electromagnetic energy extraction from a rotating black hole, is widely believed to work for driving relativistic jets, although it is still under debate how the Poynting flux is causally produced and how the rotational energy of the BH is reduced. We generically discuss the Kerr BH magnetosphere extending the arguments of Komissarov and our previous paper (Toma & Takahara 2014, MNRAS, 442, 2855), and propose a new picture for resolving issues. For the magnetic field lines threading the event horizon, we show that the concept of the steady inflow of negative electromagnetic energy which some authors claim is not physically essential. Then we build an analytical toy model of a time-dependent process both in the Boyer-Lindquist and Kerr-Schild coordinate systems, and suggest that the structure of the steady outward Poynting flux is causally constructed by the displacement current and the cross-field current. In the steady state, the Poynting flux is maintained without any electromagnetic source, and it directly reduces the BH rotational energy without being mediated by any in falling negative-energy objects.

Stellar, Intermediate and Supermassive black holes

12 Sep
11:20
Contributed

Felix Mirabel

CEA, France & IAFE, Argentina

I will review the universal physics that accounts to the common phenomena observed in stellar black holes (microquasars, LGRBs) and supermassive black holes (AGN). I will also review the impact of black hole astrophysics in fundamental physics, star formation, cosmology and gravitational wave astrophysics.

Transonic structure of slowly rotating accretion flows with shocks around black holes

12 Sep
11:35
Contributed

Petra Sukova, Agnieszka Janiuk and Szymon Charzynski

Center for Theoretical Physics PAS, Poland

I will show recent results of the studies of low angular momentum accretion of matter onto Schwarzschild and Kerr black hole using fully relativistic numerical simulations. I will compare the resulting 3D structure of transonic flows with results of 1D pseudo-Newtonian computations of non-magnetized flow, and discuss the case of magnetized accretion. Of particular interest are the results showing oscillations of the position of the shocks in the accreting flow as well as the 'hysteresis' type of behaviour in the multiple sonic points solution. Observable effects are related to black holes on the whole mass scale, in particular to the time-scales and shapes of the luminosity flares in Sgr A* or to the evolution of QPOs and their frequency during outbursts of microquasars.

What drives the growth of supermassive black holes?

12 Sep
11:50
Contributed

Akos Bogdan[1] and Andy Goulding[2]

[1]Harvard-Smithsonian Center for Astrophysics, USA; [2]Princeton University, USA

Observational studies of nearby galaxies have demonstrated correlations between the mass of the central supermassive black holes (BHs) and properties of the host galaxies, notably the stellar bulge mass or central stellar velocity dispersion. Motivated by these correlations, the theoretical paradigm has emerged in which BHs and bulges coevolve. However, this picture was challenged by observational and theoretical studies, which hinted that the fundamental connection may be between BHs and dark matter halos, and not necessarily with their host galaxies. Based on a study of 3130 elliptical galaxies, we demonstrate that the central stellar velocity dispersion exhibits a significantly tighter correlation with the total gravitating mass, traced by the X-ray luminosity of the hot gas, than with the stellar mass. This hints that the central stellar velocity dispersion, and hence the central gravitational potential, may be the fundamental property of elliptical galaxies that is most tightly connected to the larger-scale dark matter halo. These results are consistent with a picture in which the BH mass is directly set by the central stellar velocity dispersion, which, in turn, is determined by the total gravitating mass of the system.

Investigating ULXs through multiwavelength variability, broadband spectra, and theoretical modelling

12 Sep
12:05
Contributed

Luca Zampieri

INAF-Astronomical Observatory of Padova, Italy

Ultraluminous X-ray sources (ULXs) are non-nuclear extragalactic X-ray point sources with luminosity exceeding the Eddington limit for a 10 solar mass compact object. The great interest in these sources is related to the fact that they represent a privileged way to explore the distribution of black hole (BH) masses over 20 solar masses and mass accretion above the Eddington limit in the local Universe. We now

know that the ULX population may in fact hide accreting compact objects with significantly different masses, from BHs of intermediate mass, to BHs of stellar origin or to neutron stars. The existence of BHs more massive than 25-30 solar masses has been recently proven through the direct detection of gravitational waves with the Advanced LIGO. Are these BHs related to ULXs, as suggested in recent years? And what is the actual mechanism that sustains their powerful emission? We will review these and other crucial questions on the ULX nature and will present a comprehensive approach to investigating ULXs through multiwavelength variability, broadband spectra, and theoretical modelling.

Black Hole Binaries in Quiescence

12 Sep
12:20
Contributed

Charles Bailyn

Yale University, Usa and Yale-NUS College, Singapore

Most X-ray binaries are transients. They spend years to decades in a very low state, and then increase in luminosity over a few days by as much as eight orders of magnitude. The outbursts last for weeks to months before the source returns to quiescence. During quiescence, emission from the sources is dominated by the companion star, which can be used to precisely determine the orbital parameters, including the mass of the black hole (e.g. Kreidberg et al. 2012 ApJ 757, 36). But there is also emission from the residual accretion flow, which can be separated from that of the companion once the size and temperature of the companion has been determined (e.g. Cantrell et al. 2010, ApJ, 710, 1127). Studies of quiescent accretion flows have been invoked as evidence for the existence of event horizons (e.g. Narayan & McClintock 2008, NewAR 51, 733). Here I will present optical/IR data of black hole binaries in quiescence from the SMARTS 1.3 m telescope at CTIO in Chile, along with coordinated observations in other wavelength regimes. These data provide spectral energy distributions that constrain the emission mechanisms and accretion flows in the quiescent state. Observations have been conducted over almost two decades, and interesting changes in the quiescent flux are observed in several cases. These may bear on the nature of the underlying outburst cycle, and thus on the demographics of black hole binaries, a crucial input into calculations of rates for gravitational wave events.

Posters

The search for isolated stellar-mass black hole candidates based on kinematics of pulsars - their former companions in disrupted binary systems

Poster 1

Elizaveta Chmyreva, Grigory Beskin, Vladimir Dyachenko and Sergey Karpov

Special Astrophysical Observatory, Russia

We propose searching for isolated stellar-mass black hole candidates based on the idea that more than 50% of radio pulsars have originated in binary systems, now disrupted, where the other component could have evolved into a black hole prior to the second supernova event of the system, which caused its disruption. We selected 16 isolated radio pulsars with known parallaxes and relatively small characteristic ages that fit our criteria and simulated 100,000 trajectories for each, tracing them back to their presumed birth places. The smallest (and therefore, best for our purpose) birth places were derived for 4 pulsars: J0139+5814, J0922+0638, J0358+5413, and J1935+1616. Their birth places were then analyzed for possible black hole candidates. Theories predict that spectra of isolated black holes cover the entire electromagnetic range, from radio to gamma, and exhibit no lines. We therefore searched for objects with a featureless flat spectrum, similar in observational manifestations to DC dwarfs and BL Lacertae, covering all spectral ranges. To this end, we used several online catalogs to select objects that are of interest. The number of such objects varies from zero to several in different birth places. We then cross identified these objects within their error ellipses, also taking into account the ISM data. Color and spectral data were then used to classify the possible identifications, and several candidates might be promising. The critical condition for these objects to be considered black hole candidates is their super fast variability. In this work we describe the procedure, and present the first results.

Ionization instability driven outbursts in Low Mass X-ray Binaries

Poster 2

Patrycja Bagińska

Astronomical Observatory, Adam Mickiewicz University in Poznan, Poland

We show our study of outbursts observed in X-ray lightcurves of transient black hole binary systems, which are caused by an accretion disk instability mechanism. The instability is driven by partial hydrogen ionization that occurs in the outer part of the disk. When the unstable front moves toward the central object, classical outburst appears with duration from 30 up to 400 days. The shape of an outburst can be very regular with fast rise exponential decay profile (FRED) which is very characteristic for ionization instability mechanism or irregular suggesting that, besides FRED, additional flickering occurs. We use the model which predicts time dependent evolution of ionization instability in an accretion disk around black hole, assuming viscosity parameter to be proportional to the gas pressure. As a result, modelled lightcurves fit to the observed lightcurves, indicating that disk instability occurs in tested source.

Recent MAXI observations of black hole systems

Poster 3

Nobuyuki Kawai[1], Hitoshi Negoro[2], Motoko Serino[3] and Satoshi Nakahira[4] and MAXI Team

[1]Tokyo Institute of Technology, Japan; [2]Nihon University, Japan; [3]RIKEN, Japan; [4]JAXA, Japan

I present the recent results from MAXI, an all-sky X-ray Monitor on the International Space Station on black hole binaries, gamma-ray bursts, and some AGN. In 2015, MAXI detected the first outbursts of GS 1354-645 and GS 2023+338 (V404 Cyg) since their last activity in 18 years and 26 years. MAXI detected 22 GRBs in 2015, and outbursts of a few blazars. I also present on the search for X-ray counterpart of the gravitational wave event GW150914.

Prospects for the Discovery of Black Hole Binaries without Mass Accretion with Gaia

Poster 4

Norita Kawanaka[1], Tsvi Piran[2], Tomasz Bulik[3] and Masaki Yamaguchi[4]

[1]University of Tokyo, Japan; [2]Hebrew University of Jerusalem, Israel; [3]University of Warsaw, Poland; [4]Astronomical Observatory of Japan, Japan

We study the prospect for Gaia to detect black hole binary systems without the mass transfer from their companion stars. Gaia will be able to discover Galactic black holes without mass accretion by detecting the proper motion of their companion stars. We evaluate the number of such black hole binaries which have the orbital period short enough to be detected by Gaia during its operation, taking into account the binary evolution model.

GMOS IFU observations of a wandering black hole in NGC 5252

Poster 5

Minjin Kim

Korea Astronomy and Space Science, South Korea

We recently found an ultraluminous X-ray source in NGC 5252, which is a possible candidate of an off-nuclear non-stellar black hole. We present a follow-up study of the optical IFU spectrum obtained with GMOS-N/GMOS. Using the IFU data, we again confirm that the redshift of the ionized gas at the position of the ULX coincides with that of NGC 5252. The spectroscopic information of the ionized gas around the ULX reveals that the gas is rotating with the ULX. This findings possibly indicates that the ULX is NOT a background source, but the actual ionizing source of the surrounding gas. It supports the idea that the ULX is an off-nucleus AGN associated with NGC 5252. We find the maximum velocity of the rotating gas is relatively small, indicating that the progenitor of the ULX can be a nucleus of a dwarf galaxy.

Optical variability of V404 Cygni at the anomalous outburst

Poster 6

Yutaro Tachibana[1], Nobuyuki Kawai[1], Taketoshi Yoshii[1], Hidekazu Hanayama[2] and Yasuyuki Tanaka[2]

[1]Tokyo Tech, Japan; [2]Astronomical Observatory of Japan, Japan; [3]Hiroshima University, Japan

The black hole binary V404 Cygni (= GS 2023+338) went into an outburst on June 15, 2015 after 26 years of quietness. This outburst was detected by the Swift satellite and by MAXI on the ISS, and promptly reported to the astronomical community. Soon after these notifications, we started intense observation campaign of this source using the MITSuME 50cm telescope in Akeno, Yamanashi, and MURIKABUSHI Telescope in Ishigakijima Astronomical Observatory. MITSuME CCD camera attached to these telescopes enables us to obtain images in three energy bands (g, Rc, and Ic) simultaneously. Using the time domain analysis of the multi-colour optical light curves, we successfully decomposed optical variations into two components: high-variable component, and low-variable component. Although the Ha line contribution was not negligible and thus the spectral indices of these components have some uncertainties, we obtained feasible interpretations for the emission mechanisms of them. We present the methods of analyses, and the picture of the optical variation in V404 Cygni.

A pseudo-Newtonian description of any stationary space-time

Poster 7

Vojtech Witzany and Claus Laemmerzahl

ZARM, Universitaet Bremen, Germany

Since the first investigations into accretion onto black holes, astrophysicists have proposed effective Newtonian-like potentials to mimic the strong-field behavior of matter near a Schwarzschild or Kerr black hole. On the other hand, neutron stars or black holes in many of the alternative gravity theories differ from the idealized Schwarzschild or Kerr field. To resolve this, we give a Newtonian-like Hamiltonian which almost perfectly mimics the behavior of test particles in any given stationary space-time. The properties of the Hamiltonian are excellent in static space-times such as the Schwarzschild black hole, but become

worse for space-times with gravito-magnetic or dragging effects such as the Kerr metric.

Topic 2: Gamma Ray Bursts

Black Hole Systems as Multi-Messenger Sources

12 Sep
14:00
Invited

Kunihito Ioka

Yukawa Institute for Theoretical Physics, Kyoto University, Japan

We will discuss multi-messenger signals, such as gamma-ray bursts (GRBs), macronovae, and cosmic rays, of black hole systems, including mergers of two neutron stars (NS-NS) and a black hole and a neutron star (BH-NS) and collapse of population III stars and supermassive stars. If time permits, we would like to touch on topics related to the gravitational wave event GW 150914 and merged black holes.

Gamma-ray bursts: progress and problems

12 Sep
14:30
Invited

Nial Tanvir

University of Leicester, UK

In the nearly 50 years since the first gamma-ray burst was detected, considerable progress has been made in understanding the populations of gamma-ray bursts. Both the long and short varieties are now recognised as cosmological phenomena, with the former strongly associated with some class of massive stars, while increasing evidence points to the latter being created in compact object mergers. In both cases, ultrarelativistic jets are thought to be formed during accretion onto a remnant (either a black hole or magnetar); dissipation of the jet energy producing the observed prompt and afterglow radiation. I will review recent developments in the field, and highlight some of the critical remaining problems.

Gamma-ray burst spectral evolution in the internal shock model

12 Sep
15:00
Contributed

Željka Marija Bošnjak[1] and Frédéric Daigne[2]

[1]University of Rijeka, Croatia; [2]Institut d'Astrophysique de Paris, France

We have developed a time-dependent numerical model to calculate the prompt gamma-ray burst emission over a broad energy range (from soft X-ray to GeV energies). We use this code to compute gamma ray burst light curves and time-evolving spectra. The spectral evolution in this model is determined by the evolution of the physical conditions in the shocked regions of the GRB jet, and by the effective microphysics parameters that determine magnetic field strength and electron energy. I will present a comprehensive set of simulations of GRB spectral evolution and how it depends on various parameters of the jet/physics. The predictions of the model are confronted with the GRB observations in the standard sub-MeV energy range, as well as with high energy bands observed by Fermi/LAT.

Gamma-Ray Burst Polarization

12 Sep
15:35
Invited

Diego Götz[1] and Stefano Covino[2]

[1]CEA Irfu/Service d'Astrophysique, France; [2]INAF OAB, Italy

We will review the current observational and theoretical status of the polarization measurements of Gamma-ray Bursts at all wavelengths. Gamma-Ray Bursts are thought to be produced by an ultra-relativistic jet, possibly powered by a black hole. One of the most important open point is the composition of the jet: the energy may be carried out from the central source either as kinetic energy (of baryons and/or pairs), or in electromagnetic form (Poynting flux). The polarization properties are expected to help disentangling main energy carrier. The prompt emission and afterglow polarization are also a powerful diagnostic of the jet geometry. Possible implications of polarimetric measurements for quantum gravity theory testing are also briefly presented, and future perspectives for the field mentioned.

Generation and decay of the magnetic field in collisionless shocks

12 Sep
16:05
Contributed

Mikhail Garasev and Evgeny Derishev
Institute of Applied Physics, Russia

We present the numerical calculations of the collisionless shocks in the pair plasma. We use the model where the magnetic field in the incoming flow is generated by continuous injection of anisotropic electron-positron pairs. The goal of this study is to investigate the spatial scale of the fields generated in the upstream of the shock wave, the growth of the field during the passage of the shock wave and the decay of the field in the downstream. For these purposes we had performed a number of low-noise 2D PIC-simulations. We found that the gradual injection of anisotropic plasma in the upstream of the shock-wave generates the large-scale, slow decaying magnetic field that is then amplified during the passage of the shock. The magnetic field energy reached 0.01 of equipartition in maximum in our simulations, after that it slowly decays on the time scales proportional to the duration of the injection in the upstream. Thus, it could survive for a sufficiently large times, and serve as a source of GRB synchrotron radiation.

Low Lorentz Factor Jets from Compact Stellar Mergers: Candidate Electromagnetic Counterparts to Gravitational Wave Sources

12 Sep
16:20
Contributed

Gavin Lamb and Shiho Kobayashi
Liverpool John Moores University, UK

Compact binary mergers with neutron star (NS) and/or black-hole (BH) components are the progenitor of short gamma-ray bursts (GRB) and a candidate for gravitational waves (GW) detectable by advanced LIGO/Virgo. By assuming a power-law distribution of Lorentz factor (Gamma) for a population of post-merger outflows, we show that low-Gamma jets can produce on-axis orphan afterglow of failed GRB. These afterglow are a suitable candidate for electromagnetic (EM) counterpart searches to a GW trigger. A GRB will fail if the dissipative radius is less than the photospheric radius; adiabatic cooling of radiation, and the thermalisation of the spectrum below the photosphere result in the suppression of prompt gamma-ray emission. The fraction of failed GRB

from a population of NS-NS/NS-BH mergers within the LIGO/Virgo detection volume is found to be strongly dependent on the Gamma distribution. Astrophysical jets typically have a Gamma distribution with an index = -1.5, assuming this distribution for post-merger outflow of events within 300 Mpc, we find ∼65% result in failed GRB.
GRB observations indicate that low-Gamma outflows tend to have wider opening angles; for an isotropic distribution, low-Gamma failed GRB jets are more likely to be oriented towards an observer than for standard GRB. As GW are strongest on-axis, the probability of an EM counterpart oriented towards an observer is greater than for the isotropic case. By assuming a 20 degrees for all failed GRB jet opening angles, and given a GW detection, ∼20% of mergers that result in failed GRB will be oriented towards an observer. The rate of on-axis orphan afterglow with an optical peak brighter than magnitude 21 for 40(400) mergers per year would be 4(40). We show that the peak flux is typically ∼18 magnitude at optical and emission peaks ∼30 hours after a merger.

Search for High Energy emission from GRBs with MAGIC

12 Sep
16:35
Contributed

Alessio Berti on behalf of the MAGIC GRB group
INFN Trieste/Udine, Italy

Gamma-ray Bursts (GRBs) are the most violent explosions in the Universe, releasing a huge amount of energy in few seconds. Since their discovery, many space-based instruments were developed in order to understand the physics and emission processes of these enigmatic events. While our understanding of the prompt and the afterglow phases has increased with BATSE, Swift and Fermi, we have very few information about their High Energy (HE, E∼100 GeV) emission components. This requires a ground-based experiment able to perform fast follow-up with enough sensitivity above ∼50 GeV. The MAGIC telescopes (Major Atmospheric Gamma-ray Imaging Cherenkov) have been designed to perform fast follow-up on GRBs thanks to fast slewing movement and low energy threshold (∼40-50 GeV). Since the beginning of the operations, MAGIC followed-up around 80 GRBs in good observational conditions but only a small fraction of them has redshift information available from space detectors. In this talk the GCN alert system, the

MAGIC GRBs follow-up campaign and the constraints we can put by detecting HE and VHE gamma rays from GRBs will be reviewed.

GRB 110530A: Peculiar Broad Bump and Delayed Plateau in Early Optical Afterglows

12 Sep
16:50
Contributed

Shuqing Zhong[1], Liping Xin[2], Enwei Liang[1] and Jianyan Wei[2]

[1]Guangxi University, China; [2]Key Laboratory of Space Astronomy and Technology, National Astronomical Observatories, Chinese Academy of Sciences, China

We report our very early optical observations of GRB 110530A and investigate its jet properties together with its X-ray afterglow data. A peculiar broad onset bump followed by a plateau is observed in its early R band afterglow lightcurve. The optical data in the other bands and the X-ray data are well consistent with the temporal feature of the R band lightcurve. Our joint spectral fits of the optical and X-ray data show that they are in the same regime, with a photon index of $\sim$1.70. The optical and X-ray afterglow lightcurves are well fitted with the standard external shock model by considering a delayed energy injection component. Based on our modeling results, we find that the radiative efficiency of the GRB jet is about 1% and the magnetization parameter of the afterglow jet is less than 0.04 with the derived extremely low epsilon-B (the fraction of shock energy to magnetic field) of $1.64{\cdot}10^{-6}$. These results well indicate that the jet is matter dominated. Delayed energy injection from accretion of late fall-back material of its pre-supernova star is also discussed.

L_{iso}-E_p-Γ_0 Correlation of Gamma-Ray Bursts

12 Sep
17:05
Contributed

Enwei Liang
Guangxi University, China

By deriving the initial Lorentz factors of a sample of 34 gamma-ray bursts with their optical afterglow onset peaks we found a tight correlation among the Lorentz factor, the isotropic peak luminosity, and the peak energy of the νf_ν spectrum in the cosmological rest frame. This correlation is much tighter than pair correlations between the three observables. We argue that this correlation could be more physical than the Amati relation since physically the observed luminosity and peak energy not only depends on radiation physics, but also depends on the bulk motion of the jet. We discuss its physical implications for understanding GRB jet composition and radiation mechanism as well as the use for GRB cosmology.

Posters

Very Early Optical Observations of GRB 140512A : Bright Reversed Shock Emission and Implications

Poster 8

Xiaoli Huang[1], Liping Xin[2] and Enwei Liang[1]
[1]Guangxi University, China; [2]Key Laboratory of Space Astronomy and Technology, National Astronomical Observatories, Chinese Academy of Sciences, China

Reversed shock emission of gamma-ray bursts (GRBs) plays an important role in revealing the properties of the radiating fireball and its environment. We report our very early optical observations of GRB 140512A covering from 136 sec to about 8 hours after the GRB trigger and investigate its properties by using our data, together with the data observed with Swift/XRT and Fermi/GBM. Our joint spectral fit to the prompt gamma-ray, X-ray and optical data suggests that the first detection of our optical data could be the prompt optical emission. The early bright optical peak, which increases with a slope of 3 and decays with a slope of -1.94, would be the reversed emission of the fireball, similar to that observed in GRBs 990123, 090102, and 130427A. We fit the optical and X-ray afterglow data in the framework of the standard reversed and forward shock models. We find that the ratio of the fraction of internal energy to the magnetic field in the reversed shock

region to that in the forward region is ∼1000, and the ambient density is about 17 cm^{-3}.

Untriggered search for rapid optical transients with Mini-MegaTORTORA wide-field monitoring system

Poster 9

Sergey Karpov[1], G. Beskin[1], A. Biryukov[2], S. Bondar[3], E. Ivanov[3], E. Katkova [3], N. Orekhova[3], A. Perkov [3] and V. Sasyuk[4]

[1]Special Astrophysical Observatory of Russian Academy of Sciences; [2]Sternberg Astronomical Institute of Moscow State University, Russia; [3]Institute for Precise Instrumentation, Russia; [4]Kazan Federal University, Russia

Here we report an ongoing efforts for an untriggered search of rapid optical transients of various astrophysical and non-astrophysical origins on time scales down to fractions of a second with Mini-MegaTORTORA. Mini-MegaTORTORA is a novel 9-channel wide-field optical monitoring system in operation since 2014 at Special Astrophysical Observatory on Russian Caucasus. We present first results of its operation and discuss upper limits on a rapid optical 'orphan' flashes possibly related to off-axis gamma-ray bursts.

Synergetic Growth of the Rayleigh-Taylor and Richtmyer-Meshkov instabilities in the Relativistic Jet

Poster 10

Jin Matsumoto[1] and Youhei Masada[2]

[1]RIKEN, Japan; [2]Aichi University of Education, Japan

The radial oscillating motion of the jet is naturally excited due to the pressure mismatch between the jet and surrounding medium, that is, cocoon when the jet propagates through an ambient medium. In the rest frame of the decelerating jet interface that expands radially, an effective inertia force acts on the interface and is directed outward. Therefore the jet medium is on top of the cocoon medium in the effective gravity in this frame and the Rayleigh-Taylor instability is expected to grow at the interface. We investigate the growth of the Rayleigh-Taylor instability at the interface of the jet using three-dimensional hydrodynamic simulations. The propagation of the relativistic jet that

is continuously injected from the boundary of the calculation domain into a uniform ambient medium is solved. We find that the interface of the jet is deformed by a synergetic growth of the Rayleigh-Taylor and Richtmyer-Meshkov instabilities regardless of the launching condition, such as the specific enthalpy of the jet or the effective inertia ratio between the jet and ambient medium. The material mixing between the jet and external medium due to these instabilities causes the deceleration of the jet.

Ultra-long gamma-ray bursts from supermassive population III stars

Poster 11

Tatsuya Matsumoto[1], Daisuke Nakauchi[2], Kunihito Ioka[1], Alexander Heger[3] and Takashi Nakamura[1]

[1]Kyoto University, Japan; [2]Tohoku University, Japan; [3]Monash University, Australia

The existence of black holes (BHs) of mass $\sim 10^9$ $M_\odot$ at $z < 6$ is a big puzzle in astrophysics because even optimistic estimates of the accretion time are insufficient for stellar-mass BHs of $\sim$10 $M_\odot$ to grow into such supermassive BHs. A resolution of this puzzle might be the direct collapse of supermassive stars with mass $M \sim 10^5$ $M_\odot$ into massive seed BHs. We find that if a jet is launched from the accretion disk around the central BH, the jet can break out of the star because of the structure of the radiation-pressure-dominated envelope. Such ultralong gamma-ray bursts with duration of $\sim 10^4 - 10^6$ s and flux of $\sim 10^{-11} - 10^{-8}$ erg s^{-1} cm^{-2} could be detectable by Swift. We estimate an event rate of <1 yr^{-1}. The total explosion energy is $\sim 10^{55} - 10^{56}$ erg. The resulting negative feedback delays the growth of the remnant BH by about 70 Myr or evacuates the host galaxy completely. Furthermore, we show that the energy injected from the jet into a cocoon is huge $\sim 10^{55} - 10^{56}$ erg, so that the cocoon fireball is observed as an ultra-luminous supernova of $\sim 10^{45} - 10^{46}$ erg s^{-1} for $\sim$5000[(1 + z) 16] days. They will be detectable by future telescopes with near-infrared bands, such as Euclid, WFIRST, WISH, and JWST up to $z \sim 20$ and $<$10 events per year, providing direct evidence of the DCBH scenario.

Spatial Distribution of the Gamma-ray Bursts and the Cosmological Principle

Poster 12

Attila Mészáros

Charles University, Czech Republic

The Cosmological Principle claims that "in the large scale average the visible parts of our universe are isotropic and homogeneous." (P.J.E. Peebles, Principles of Physical Cosmology, Princeton University Press, 1993, page 15). In year 1998 the author, together with his two colleagues, discovered that the BATSE's short gamma-ray bursts are not distributed isotropically on the sky (Balazs L.G., Meszaros A., Horvath I., Astronomy and Astrophysics, 339, 1, 1998). This first discovery was followed by several other ones confirming both the existence of bold anisotropies in the angular distribution of bursts and the existence of huge Gpc structures in the spatial distribution of the bursts. All this means that these anisotropies reject the Cosmological Principle, because no large scale averaging can be provided (Meszaros A. et al., Baltic Astronomy, 18, 293, 2009; Meszaros A. et al., Sixth Huntsville GRB Symposium, AIP Conf. Proc., Vol. 1133, 483, 2009). The aim of this contribution is to survey these publications since 1998 till today.

Topic 3: Tidal Disruption Events

Observational Progress in Identifying and Characterizing Tidal Disruption

13 Sep
8:30
Invited

Brad Cenko

NASA Goddard Space Flight Centre and University of Maryland, USA

I will present an overview of efforts across the electromagnetic spectrum to identify and study tidal disruption events (TDEs), when a star wanders too close to a super-massive black hole and is torn apart by tidal forces. In particular I will focus on three unexpected surprises that challenge the most basic analytic picture of these events:
1) large inferred radii for the optical/UV-emitting material, indicating either circularization of the bound debris at large distances and/or significant reprocessing of the radiation from the inner accretion disk;
2) the ubiquity of outflows, detected at radio, X-ray, and UV wavelengths, ranging from speeds of 100 km/s to near the speed of light; and,
3) the peculiar atomic abundances observed in the UV and optical spectra of these objects. I will also discuss the luminous transient ASASSN-15lh, whose origin as a TDE or super-luminous supernova is currently actively debated.

Stellar Tidal Disruption: what can we learn and what have we learned

13 Sep
9:00
Invited

Enrico Ramirez-Ruiz

University of California, USA

In the last several years, the disruption and accretion of stars by supermassive black holes (SMBHs) has been linked to tens of luminous flares observed in the cores of nearby galaxies. Our theoretical understanding of these tidal disruption events (TDEs), however, remains incomplete. While recent simulations have provided unprecedented detail on the dynamics of the disruption, we still do not have a good understanding of how infalling gas circularizes and accretes onto the SMBH, or how or where the thermal emission we observe is generated. The art of modeling the tidal disruption of stars by massive black holes forms

the main theme of my talk. Detailed simulations should tell us what happen when stars of different types get tidally disrupted, and what radiation a distant observer might detect as the observational signature of such events.

Radiation mechanism and composition of relativistic jets in TDEs

13 Sep
9:30
Invited

Pawan Kumar

University of Texas, Austin, USA

Relativistic jets are observed in systems such as pulsars, AGNs, micro-quasars, GRBs etc. However, in spite of the work in the last more than 30 years we don't yet understand some basic properties of these jets such as whether the jet energy is primarily in the form of magnetic fields or the kinetic energy of matter. In a few cases, relativistic jets are also produced when a star is tidally disrupted by a super-massive black hole (TDE); these events turn out to be very useful for answering the basic question of jet composition. I will describe one particular tidal disruption event, and discuss the mechanism by which X-rays were produced in this case and the composition of the relativistic jet that was inferred. Predictions for the reprocessed IR radiation by dust in the nuclear region of the TDE host galaxy, and recent observational confirmation will also be described.

The role of electromagnetism in tidal disruption events

13 Sep
10:00
Contributed

Andrej Čadež

Faculty of Mathematics and Physics, University of Ljubljana, Slovenia

Tidal disruption events, detectable as violent explosions observable in almost all bands of electromagnetic spectrum as well as energetic activity of compact stars and black holes are often organized on a scales reaching far from the expected gravitational range of the central source. We would like to argue that these phenomena may well have to do with large scale electromagnetic fields generated in non-equilibrium conditions. We will show a possible mechanism which may produce large

scale electric and magnetic field in a rarified nebulae surrounding a rotating compact objects and show how such fields may shape the nebulae.

Relativistic loss cone dynamics: Infall and inspiral rates and branching ratios

13 Sep
10:35
Invited

Tal Alexander

Weizmann Institute of Science, Israel

I describe some open issues and recent advances in the understanding and modeling of relativistic stellar dynamics around a massive black hole (MBHs), and the implications for the rates of infall (e.g. tidal disruption) and inspiral (e.g. gradual decay by gravitational wave emission) processes, and their branching ratios.

Hypervelocity Stars: tidal disruption of binaries by a massive black hole

13 Sep
11:05
Contributed

Shiho Kobayashi[1], Harry Brown[1], Elena Maria Rossi[2] and Re'em Sari[3]

[1]Liverpool John Moores University, UK; [2]Leiden University, Netherlands;[3]Hebrew University of Jerusalem, Israel

We discuss the tidal disruption of binaries by a massive point mass (e.g. the massive black hole at the Galactic centre). We show that the restricted three-body approximation provides a simple and clear description of the dynamics. In this framework, results can be simply rescaled in terms of binary masses, their initial separation, and the binary-to-black hole mass ratio. For general binary orientations, we provide the probability distributions for disruption of circular binaries and for the ejection energy. Interestingly, deep-reaching binaries separate widely after penetrating the tidal radius, but always approach each other again on their way out from the BH. The implications to hypervelocity stars and the gravitational wave event GW150914 are discussed.

Star Formation Close to the Supermassive Black Hole Sgr A*

13 Sep
11:20
Contributed

Farhad Yusef-Zadeh

Northwestern University, USA

A critical question regarding star formation near supermassive black holes (SMBHs) is whether tidal shear in the vicinity of SMBHs is able to completely suppress star formation or induces star formation. There are currently two modes of star formation that are considered to explain the origin of young stars near Sgr A*. One is the standard cloud-based mode of star formation observed in the Galactic disk. The other is disk-based of star formation, which explains the disk of stars orbiting Sgr A*, is entirely distinct from cloud-based mode. I will discuss each of these modes of stars formation and how they apply to the large number of young massive stars and low-mass stellar candidates found within few lights years of Sgr A*.

Fermi LAT's view of the centre of our Galaxy

13 Sep
11:35
Contributed

Gabrijela Zaharijas[1]on behalf of the Fermi LAT collaboration, Pasquale Serpico[2] and Jovana Petrovic[3]

[1]University of Nova Gorica, Slovenia; [2]LAPTh, Annecy, France; [3]University of Belgrade, Serbia

The Fermi-LAT gamma-ray data in the inner Galaxy region show several prominent features possibly related to the past activity of the Milky Way's super massive black hole. At a large, 50 deg scale, the Fermi LAT revealed symmetric hour glass structures with hard energy spectra extending up to 100 GeV (and dubbed 'the Fermi bubbles'). More recently and closer to the Galactic centre, at the 10 deg scale, several groups have claimed evidence for excess gamma-ray emission that appears symmetric around the Galactic center and has an energy spectrum peaking at few GeVs.
In this talk I will review the LAT data analysis of these two emission components and discuss their robustness and possible origins. In that context, I will explore the possibility of inverse Compton emission from high-energy electrons produced in a short duration, burst-like event injecting $10^{52} - 10^{53}$ erg, roughly 10^6 yrs ago. Several lines of evidence suggest that a series of 'burst like' events happened in the vicinity of

our black hole in the past and gamma-ray observations may offer a new view of that scenario.

Swift J1644+5734: the EVN view

13 Sep
11:50
Contributed

Zsolt Paragi[1], Jun Yang[2], Alexander van der Horst[3], Leonid Gurvits[1], Bob Campbell[1], Dimitrios Giannios[4], Tao An[5] and Stefanie Komossa[6]

[1]JIVE, Netherlands; [2]Onsala Space Observatory, Sweden;[3]George Washington University, USA;[4] Purdue University, USA; [5] Shanghai Astronomical Observatory, China ; [6]MPIfR-Bonn, Germany

Very Long Baseline Interferometry (VLBI) is a powerful tool to probe compact radio emission from Galactic and extragalactic transients. The European VLBI Network (EVN) provides images on scales of milliarcseconds (1 mas corresponds to ∼1 AU at 1 kpc, or 1 pc at 200 Mpc distance) down to typical limiting flux densities of ∼100 μJy (5-10 sigma).
In this presentation we highlight the EVN result on the first confirmed relativistic-jet tidal disruption event (TDE). Swift J1644+5734 was monitored with the EVN at 5 GHz between April 2011 and March 2015 to directly measure the apparent speed of the ejecta in the radio. In the initial real-time correlation e-EVN run we identified a very nearby compact source that was used as a position reference for the following astrometry observations. This way we achieved a statistical astrometric precision about 12 μas (68% confidence level) per epoch. Even with this top-level astrometric result, we did not detected proper proper motion in Swift J1644+5734 radio ejecta. We conclude that the apparent average ejection speed between 2012.2 and 2015.2 was less than 0.3c with a confidence level of 99%. This tight limit is a direct observational evidence for either a very small viewing angle or a strong jet deceleration due to interactions with a dense circumnuclear medium, in agreement with some recent theoretical studies.

Tidal disruption events seen in the XMM-Newton slew survey

13 Sep
12:05
Contributed

Richard Saxton[1], Stefanie Komossa[2], Andy Read[3] and Paulina Lira[4]
[1]XMM SOC, ESAC, Spain; [2]MPIFR, Germany; [3]University of Leicester, UK; [4]Observatorio Astronomico Nacional Cerro Calan, Chile

The XMM-Newton performs a survey of the sky in the 0.3-10 keV X-ray band while slewing between observation targets. The sensitivity in the soft X-ray band is comparable with that of the ROSAT all-sky survey, allowing bright transients to be identified in near real-time by a comparison of the flux in both surveys. Several of the soft X-ray flares are coincident with galaxy nuclei and five of these have been interpreted as candidate tidal disruption events (TDE). The first three discovered had a soft X-ray spectrum, consistent with the classical model of TDE, where radiation is released during the accretion phase by thermal processes. These are similar to the first TDE candidates discovered by ROSAT in the 1990s. The remaining two have an additional hard, power-law component, which in only one case was accompanied by radio emission. We reflect on the nature of this hard component and assess whether it originates in a jet, similar to an off-axis version of the high-luminosity, relativistic Swift-discovered TDE, or whether it comes from an AGN-like comptonisation region.

TDEs in OGLE and Gaia surveys

13 Sep
12:20
Contributed

Łukasz Wyrzykowski and Aleksandra Hamanowicz
Warsaw University Astronomical Observatory, Poland

TDEs allow to probe the supermassive black holes (SMBH) in the cores of galaxies and could be a source of black hole mass growth. We will present the first candidates for TDEs found by OGLE and Gaia surveys. We will show results from a preliminary study, indicating that TDEs can occur in cores of galaxies exhibiting different levels of activity, from quiescent, through weak-AGNs to highly active QSOs.

Posters

Tidal disruption events from different kinds of astrophysical objects: a preliminary analysis

Poster 13

Aurora Clerici and Andreja Gomboc
University of Nova Gorica, Slovenia

Tidal disruption events (TDEs) are useful tools to study quiescent black holes (BHs). In the last two decades, the interest for these astrophysical phenomena has grown due to the availability of more observational data. Furthermore, with the growing power of computers, simulations of TDEs are accessible, providing new data to test both theoretical models and observational data. The main theory states that about half of the debris released from a disrupted star is bound to the BH, circularizes and eventually accretes, while the other half is unbound. Even though a lot of work has been done on TDEs, there are important aspects which are yet not fully understood, for example, the main mechanisms governing the circularization process, how is energy released and where are the radio, optical/UV and X-ray radiations produced. Massive black holes (MBHs) can be found in the center of galaxies. The nearest MBH is the one residing in the Galactic Center (GC), which, thanks to its proximity, provides us the possibility to study the MBH environment in detail. Also, the GC environment harbours a variety of astrophysical objects. While the study of the bound debris of a TDE can give us direct information regarding the BH, the unbound debris can provide us data about the surrounding environment. In this respect, we're investigating the possible outcomes of the tidal disruption of stars, planets and asteroids. The main goal is to highlight the different physical parameters governing the tidal disruptions and, from these, obtain a better und

Explosive nucleosynthesis in tidal disruption events of massive white dwarfs, and their debris

Poster 14

Ataru Tanikawa[1], Yushi Sato[1], Ken'ichi Nomoto[1], Keiichi Maeda[2], Naohito Nakasato[3] and Izumi Hachisu[1]

[1]The University of Tokyo, Japan; [2]Kyoto University, Japan; [3]University of Aizu, Japan

We investigate nucleosynthesis and hydrodynamic signatures of tidal disruption events (TDEs) of massive white dwarfs (WDs) by intermediate mass black holes (IMBHs), by means of smoothed particle hydrodynamics simulations coupled with nuclear reactions. The reason for investigating the massive WDs is that WDs more massive than $1.0M_{\odot}$ should make an encounter with an IMBH more frequently than less massive WDs in a dynamically old stellar system due to dynamical effects. Such massive WDs possibly have various compositions. Therefore, we consider four WD models with different compositions: a carbon-oxygen (CO) WD, a carbon-oxygen-neon (CONe) WD, an oxygen- neon-magnesium (ONeMg) WD, and a hybrid CONe WD. All the WD models experience explosive nuclear burning, and synthesize a substantial amount of radioactive nuclei, such as 56Ni. These TDEs can be observed as optical transients similar to Type Ia supernovae (SNe Ia), even if WDs have ONeMg compositions. We discuss expected observational signatures of TDEs that can be used to distinguish TDEs from SNe Ia.

Stellar and gas dynamical model for tidal disruption events

Poster 15

Mageshwaran Tamilan and Arun Mangalam

Indian Institute of Astrophysics, India

A supermassive black hole influences the orbital and spatial distribution of stars in the inner parsec region of its host galaxy which together determine the ingestion rate of stars; this results in tidal disruption events (TDEs) where the stars are disrupted by the strong tidal gravity of the hole. We have constructed a model of TDE using stellar dynamical and gas dynamical inputs that include black hole (BH) mass $M_{\bullet}$, specific orbital energy E and angular momentum J and star mass $M_{\star}$ and radius $R_{\star}$. By using orbital elements of the star, namely the energy and

angular momentum, we make predictions for the physical parameters of the disk that is formed after a TDE. We have solved the Fokker Planck equation for the galactic density $\rho \propto r^{-\gamma}$, and stellar mass function $\xi(m) \propto m^{\alpha}$ (Kropua 2001) where $m = M_{\star}/M_{\odot}$ and obtained the feeding rate of stars to the BH integrated over the phase space as $\dot{N}_t \propto M_{\bullet}^{\beta}$, where $\beta = -0.3 \pm 0.01$ for $M_{\bullet} > 10^7 M_{\odot}$ and $\sim 6.8 \times 10^{-5}$ yr^{-1} for $\gamma = 0.7$. We simulated the light curve profiles by considering an accretion disk with steady structure and time varying accretion rate. Using this, standard cosmological parameters and instrument details, we predict the detectable rates for various ongoing and forthcoming All Sky Surveys. We have also built the time evolution of the accretion disk in both super and sub Eddington phases self-consistently by taking into account the wind outflow in the super Eddington phase and simulated the light curve profiles in various spectral bands. We have fit our model to observations in X-ray and Optical bands and derived the orbital parameters of the stars, E, J, $M_{\star}$ and $R_{\star}$ and black hole mass $M_{\bullet}$.

Topic 4: Active Galactic Nuclei

Observational view of magnetic fields in AGN jets

13 Sept
14:00
Invited

Talvikki Hovatta
Aalto University, Finland

According to the currently favoured picture, relativistic jets in active galactic nuclei (AGN) are launched in the vicinity of the black hole by magnetic fields extracting energy from the spinning black hole or the accretion disk. In the past decades, various models from shocks to magnetic reconnection have been proposed as the energy dissipation mechanism in the jets. In my talk, I will review how polarization observations can be used to constrain the magnetic field structure in the jets of AGN, and how the observations can be used to constrain the models. I will show examples of both optical and radio observations, including Faraday rotation maps that give us insights into the 3D structure of the magnetic field in the parsec-scale jets.

Ultrafast VHE Gamma-Ray Flares of AGN

13 Sept
14:30
Invited

Maxim Barkov
University of Potsdam, Germany

For a typical mass range of black holes in powerful AGN, M 108M, the imaging atmospheric Cherenkov telescopes arrays have a unique potential for exploring the physics of black holes close to the event horizon on timescales significantly shorter than its light crossing time, which was expected to be the shortest time-scale characterizing the variability of the nonthermal emission from AGNs. This expectation is based on a fundamental effect: if the jet perturbations propagate from the central engine, e.g., in the form of sequence of blobs ejected with different Lorentz factors (leading to internal shocks), the size of the emitter in the laboratory frame does not depend on the Doppler factor. However, observations with Cherenkov detectors of several AGNs, in particular of PKS $\sim$ 2155-304, IC310 and Mkn 501, revealed a clear evidence for a shorter variability. In this talk we will discuss, in general terms, three scenarios that have been proposed for explanation of ultra-fast variability in AGNs: (i) Production of emission in magnetospheric gaps

occupying a small fraction of the entire magnetosphere; (ii) Emission by sources that move relativistically in the jet reference frame (the most feasible realization of this scenario is the magnetic field reconnection in a highly magnetized jet); (iii) flares that are initiated by penetration of external obstacles (stars or clouds) into the jet. While all these scenarios can explain, in principle, the detected variability on scales shorter than BH light crossing time, there are important additional requirements that should be fullfiled: (1) the overall energy budget should be feasible, (2) the emitter should be optically thin, i.e. gamma rays should be able to escape their production region without significant absorption, (3) the proposed radiation mechanism should be able to explain the detected spectral features of gamma-radiation.

Optical and Radio variability of the Northern VHE gamma-ray emitting BL Lac objects

13 Sept
15:00
Contributed

Elina Lindfors[1], Talvikki Hovatta[2] and Kari Nilsson[3]

[1]Tuorla Observatory, Department of Physics and Astronomy, University of Turku, Finland; [2]Aalto University, Finland; [3]University of Turku, Finland

In this talk, I will present results of a first detailed study on the optical and radio variability properties of the most numerous extragalactic VHE gamma-ray emitting sources, BL Lac objects. In this study, we used the variability information to distinguish multiple emission components in the jet, to be used as a guidance for spectral energy distribution modelling. Our sample included 32 objects in the Northern sky that have data for at least 2 years in both bands. We used optical R-band data from the Tuorla blazar monitoring program and 15 GHz radio data from the Owens Valley Radio Observatory blazar monitoring program. We estimated the variability amplitudes using the intrinsic modulation index, and study the time-domain connection by cross-correlating the optical and radio light curves. Our sample objects are in general more variable in the optical than radio. We found correlated flares in about half of the objects, and correlated long-term trends in more than 40% of the objects. In these objects we estimated that at least 10%-50% of the optical emission originates in the same emission region as the radio, while the other half is due to faster variations not seen in the radio. This implies that simple single-zone spectral energy distribution models are not adequate for many of these objects.

Multi-wavelength study from radio to TeV of the most extreme X-ray flaring activity of the high-peaked BL Lac Mrk 501

13 Sept
15:15
Contributed

Josefa Becerra Gonzalez[1], David Paneque[2], Fabrizio Tavecchio[3], Koii Noda[2] and Kazuma Ishio[2]

[1]NASA Goddard Space Flight Center, USA; [2]MPI, Germany; [3]INAF Osservatorio Astronomico di Brera, Italy

The high-frequency-peaked BL Lac object Markarian 501 is a very high energy (VHE, E 100 GeV) emitter located in our extragalactic neighborhood (z=0.034). The source can be detected in the VHE band during low state, what makes this target an ideal source for long-term multi-wavelength studies covering the entire electromagnetic spectrum. During a multi-wavelength campaign in 2014, the source showed the highest X-ray activity observed by Swift-XRT during the last decade. The source displayed very hard spectra at X-ray and gamma-ray energies with variability on day timescales. The temporal evolution of the broadband SED, studied during 2 weeks on a day-by-day basis, suggests the existence of ultra-energetic electron energy distributions contributing to the broadband emission of Mrk501. At this conference, I will report on this unprecedented flaring event and its physical implications in the multi-wavelength context.

Monitoring of the radio galaxy M87 at Very High Energy with MAGIC during a low emission state between 2012 and 2015

13 Sept
15:30
Contributed

Cornelia Arcaro[1], Priyadarshini Bangale[2], Marina Manganaro[3,4], Daniel Mazin[2,5], Piere Colin[2], Ievgen Vovk[2], Karl Mannheim[6], Kazuhiro Hada[7], Helen Jermak[8], Juan Madrid[9], Francesco Massaro[10,11], Stephan Richter[12], Felix Spanier[6] and Craig Walker[13]

[1]Università di Padova and INFN, Italy; [2]Max-Planck-Institut fuür Physik, Germany; [3]Inst. de Astrofísica de Canarias, Spain; [4]Universidad de La Laguna, Dpto. Astrofísica, Spain; [5]Institute for Cosmic Ray Research, University of Tokyo, Japan; [6]Universität Würzburg, Germany, for the MAGIC Collaboration; [7]Mizusawa VLBI Observatory, National Astronomical Observatory of Japan, Japan; [8]Liverpool John Moores University, UK; [9]CSIRO, Astronomy and Space Science, Australia; [10]Dipartimento di Fisica, Università degli Studi di Torino, Italy; [11]Istituto

Nazionale di Fisica Nucleare, Italy; [12]Centre for Space Research, North-West University, South Africa; [13]National Radio Astronomy Observatory, USA

We present the results from observing the nearby radio galaxy M87 for 156 hours (between the years 2012 and 2015) with the MAGIC telescopes. These deep observations lead to a significant very high energy (VHE, E 100 GeV) detection of the source in quiescent states each year reaching energies of up to 10 TeV. Our VHE analysis combined with quasi-simultaneous data at other energies (from gamma-rays, X-rays, optical and radio) provides a unique opportunity to study the source variability and its broadband spectral energy distribution, is found to disfavor a one-zone synchrotron/synchrotron self-Compton model. Therefore, other alternatives scenarios for the photon emission are explored. We also find that the VHE emission is compatible with being produced at the source radio core as previous data already indicated.

The extremes of AGN variability

13 Sept
16:05
Contributed

Stefanie Komossa

MPIfR, Germany

High-amplitude variability of AGN provides us with unique insights on accretion physics under extreme conditions. I present results from our ongoing monitoring campaigns (with Swift, XMM, Effelsberg, and and multi-waveband) on some of the most highly variable AGN known, including the highest-amplitude outbursts observed todate, deep low-states, unexpected long-term trends, systems which exhibit extreme Seyfert-type transitions in the optical and X-rays, and radio follow-ups of a candidate supermassive binary black hole system.

X-ray fluctuation timescale and BH mass relation in AGN

13 Sept
16:20
Contributed

Amri Wandel[1] and Mathew Malkan[2]

[1]Hebrew Univ. of Jerusalem, Israel; [2]UCLA, USA

We analyze the fluctuations in the X-ray flux of 20 AGN (mainly Seyfert 1 galaxies) monitored by RXTE and XMM-Newton with a sampling frequency ranging from hours to years, using structure function (SF) analysis. We derive high quality SFs over four orders of magnitude (0.03-300 days). Most objects show a characteristic time scale, where the SF flattens or changes slope. Comparing this SF-break time scale to the published power-spectral density (PSD) break time scale shows a fair agreement. We find a significant correlation between the SF timescale and the mass of the central black hole, determined mostly by reverberation mapping.

Periodic optical variability of AGN

13 Sept
16:35
Contributed

Edi Bon[1], Nataša Bon[1] and Paola Marziani[2]

[1]Astronomical Observatory, Belgrade, Serbia; [2]INAF, Italy

Here we present the evidence for periodicity of optical emission detected in several AGN. Periodicities are found in light curves and radial velocity curves. We discuss possible mechanisms that could produce such periodic variability and their implications. The results are consistent with possible detection of the orbital motion in proximity of their supermassive black holes.

Year long oscillations of blazars

13 Sept
16:50
Contributed

Stefano Covino[1], Angela Sandrinelli[2] and Aldo Treves[2]
[1]Osservatorio di Brera, Italy; [2]Università dell'Insubria, Como, Italy

Blazars are the main constituents of the extragalactic gamma-ray sky and light curves of the brightest ones have been produced since 2008 by the FERMI satellite in the 100 MeV – 100 GeV band. In three sources PKS 2155-304, PG1553+113 and PKS 0537-441 rather significant peaks in the periodogram at T $\sim$ 1 year are found, and they are related to periods observed in the optical-NIR light curves. The phenomenon seems to be present also in other blazars. Oscillations in blazars light curves may have similarities with the year like periodicities recently reported in the optical band for some quasars. An intriguing, but as yet not proven scenario is that in both cases the periodicities are to be ascribed to a bound system of two supermassive black holes.

Periodic quasars from PTF as milliparsec supermassive black hole binary candidates

13 Sept
17:05
Contributed

Maria Charisi[1], Imre Bartos[1], Zoltan Haiman[1], Adrian Price-Whelan[1], Matthew Graham[2], Eric Bellm[2], Russ Laher[2] and Szabolcs MArka[1]
[1]Columbia University, USA; [2]California Institute of Technology, USA

Periodic quasars from PTF as milliparsec supermassive black hole binary candidates Abstract: Supermassive Black Hole Binaries (SMBHBs) should be fairly common in galactic nuclei as a result of frequent galaxy mergers. The binaries are expected to spend a significant fraction of their lifetimes at sub-parsec separations. Hydrodynamical simulations of circumbinary disks predict that the mass accretion rate onto the BHs is periodically modulated on timescales comparable to the orbital period of the binary. Therefore, SMBHBs may be recognized by the periodic modulation of their brightness. We performed a systematic search for periodic variability in a large sample of quasars, in the photometric database of the Palomar Transient Factory. We identified several quasars with statistically significant periodicity and short periods of a few hundred days. If we associate the observed periods to the redshifted orbital period of the binaries, we conclude that the binaries

have orbital separations of a few milliparsecs. Additionally, our findings are consistent with a population of unequal mass binaries, with a typical mass ratio of q=M2/M1∼0.01.

Radio and gamma-ray loud narrow-line Seyfert 1 galaxies in the spotlight

13 Sept
17:20
Contributed

Vassilis Karamanavis, S. Komossa, E. Angelakis, I. Myserlis, L. Fuhrmann and J. A. Zensus

Max-Planck-Institut für Radioastronomie (MPIfR), Germany

Narrow-line Seyfert 1 (NLS1) galaxies provide us with unique insights into the drivers of AGN activity under extreme conditions. Given their near-Eddington accretion rates and low BH masses, they represent a class of galaxies with rapidly growing SMBHs in the local universe. A fraction of them is radio-loud and gamma-ray flaring. These provide us with tight new constraints on the physics of the formation and evolution of powerful radio jets, and in an environment not probed by classical blazars.
Here, we present the results from our Effelsberg multi-frequency radio flux monitoring and spectroscopy of a sample of gamma-ray loud NLS1 galaxies, including systems only discovered recently, and including the nearest, and the most distant gamma-ray emitting NLS1 known today. We also present high-resolution radio imaging of the NLS1 galaxy 1H 0323+342, which is remarkable for its spiral or ring-like host, unexpected in view of its blazar-like radio properties. We discuss implications for the nature of NLS1 galaxies and 1H 0323+342 in particular.
Finally, we present new radio data of the candidate gamma-emitting NLS1 galaxy RX J2314.9+2243, which is characterized by a very steep radio spectrum, unlike other gamma-ray emitting NLS1s, and shows other extreme multiwavelenght properties.

The jet properties of radio-loud Narrow-line Seyfert 1 galaxies

13 Sept
17:35
Contributed

Minfeng Gu

Shanghai Astronomical Observatory, CAS, China

Radio-loud narrow line Seyfert 1 galaxies (RLNLS1s) are very special, because some of them show blazar-like characteristics, while others resemble to compact steep-spectrum sources. Relativistic jets were shown to exist in a few RLNLS1s based on VLBI observations and confirmed by the gamma-ray flaring of some of them. These properties are unexpected, in light of the low black hole masses, high accretion rates, and possible spiral hosts of these RLNLS1s. Therefore, the investigation of the jet properties in these sources will be great helpful in understanding the jet formation in AGNs. In 2013, we started the systematic studies on the jet properties of RLNLS1s by using the Very Long Baseline Array (VLBA) observations. In this talk, we present the compact radio structure of 33 RLNLS1s from the VLBA observations at 5 GHz, which were performed with the total observing time of about 40 hours in 2013 and 2014. Before our observations, only about a dozen of RLNLS1s have published VLBI studies, thus our sample is the largest sample on the VLBI studies up to now. The implications on the jet formation are discussed based on the pc-scale jet properties, and the most recent progress and future outlook will also be given. (see Gu et al. 2015, ApJs, 221, 3 for part of the results)

Elusive accretion discs in low luminosity AGN

13 Sept
17:50
Contributed

Juan Antonio Fernandez-Ontiveros[1], Almudena Prieto[2] and Sera Markof[3]

[1]Istituto di Astrofisica e Planetologia Spaziali (INAF-IAPS), Italy; [2]Instituto Astrofisica Canarias (IAC), Spain; [3]Anton Pannekoek Institute of Astronomy, University of Amsterdam, Netherlands

Low luminosity AGN represent the vast majority of the AGN population in the near universe, and still the least conforming class with the standard AGN scenario. Their low luminosity is at odds with their often very high black hole masses and powerful jets.
I will review the challenges that parsec-scale observations across the electromagnetic spectrum of some of the nearest ones are opening on

the true nature of their emission, their transition from the most luminous to the feeble ones, and their accretion power. The strict limits imposed by these observations on their accretion power are confronted with the high mechanical inferred for their jets. Possible scenarios for these nuclei including the extraction of power form the black hole spin are discussed.

Remarkable Stability of AGN Jets

14 Sept
8:30
Invited

Serguei Komissarov[1] and Oliver Porth[2]
[1]University of Leeds, UK; [2]University of Frankfurt, Germany

In stark contrast to their laboratory and terrestrial counterparts, cosmic jets appear to be very stable. They are able to penetrate vast spaces, which exceed by up to a billion times the size of their central engines. We propose that the reason behind this remarkable property is the loss of causal connectivity across these jets, caused by their rapid expansion in response to the fast decline of the external pressure with the distance from the "jet engine". In atmospheres with power-law pressure distribution, the total loss of causal connectivity occurs, when the power index exceeds 2, the steepness which is expected to be quite common for many astrophysical environments. Cosmic jets may become globally unstable when they enter flat sections of external atmospheres. We propose that the Fanaroff-Riley morphological division of extragalactic radio sources into two classes is related to this issue. In particular, we argue that the low power FR-I jets become re-confined, causally connected and globally unstable on the scale of galactic X-ray coronas, whereas more powerful FR-II jets re-confine much further out, already on the scale of radio lobes, and remain largely intact until they terminate at hot spots.

The high-efficiency jets magnetically accelerated from a thin disk in powerful lobe-dominated FRII radio galaxies

14 Sept
9:00
Contributed

Shuangliang Li

Shanghai Astronomical Observatory, China

A maximum jet efficiency line R $\sim$ 25 (R $= L_{\rm jet}/L_{\rm bol}$), found in FRII radio galaxies by Fernandes et al., was extended to cover the full range of jet power by Punsly. Recent general relativistic magnetohydrodynamic simulations of jet formation have mainly focused on the enhancement of jet power. In this work, we suggest that the jet efficiency could be very high even for conventional jet power if the radiative efficiency of disks was much smaller. We adopt the model of a thin disk with magnetically driven winds to investigate the observational high-efficiency jets in FRII radio galaxies. It is found that the structure of a thin disk can be significantly altered by the feedback of winds. The temperature of a disk gradually decreases with increasing magnetic field; the disk density, surface density, and pressure also change enormously. The lower temperature and higher surface density in the inner disk result in the rapid decrease of radiative efficiency. Thus, the jet efficiency is greatly improved even if the jet power is conventional. Our results can explain the observations quite well. The theoretical maximum jet efficiency of R $\sim$ 1000 suggested by our calculations is large enough to explain all of the high jet efficiency in observations, even considering the episodic activity of jets.

Particle-in-cell Simulations of Global Relativistic Jets with Helical Magnetic Fields

14 Sept
9:15
Contributed

Ioana Dutan[1], K.-I. Nishikawa[2], Y. Mizuno[3], J. Niemiec[4], O. Kobzar[4], M. Pohl[5,6], J. L. Gómez[7], A. Peer[8], J. T. Frederiksen[9], A. Nordlund[9], A. Meli[10], H. Sol[11], P.E. Hardee[12] and D. H. Hartmann[13]

[1]Institute of Space Science, Bucharest, Romania; [2]Department of Physics, University of Alabama in Huntsville, USA; [3]Institute for Theoretical Physics, Goethe University, Frankfurt am Main, Germany; [4]Institute of Nuclear Physics, Krakow, Poland; [5]Institut fuer Physik und Astronomie, Universität Potsdam, Germany; [6]DESY, Potsdam, Germany; [7]Instituto de Astrofísica de Andalucía, Granada, Spain; [8]Physics Department, University College Cork, Ireland; [9]Niels Bohr Institute, University of Copenhagen,

Denmark; [10]Department of Physics and Astronomy, University of Gent, Belgium; [11]Observatore de Paris-Meudon, France; [12]Department of Physics and Astronomy, The University of Alabama, Tuscaloosa, USA; [13]Department of Physics and Astronomy, Clemson University, USA

We study the interaction of relativistic jets with their environment, using 3-dimensional relativistic particle-in-cell simulations for two cases of jet composition: (i) electron-proton ($e^- - p^+$) and (ii) electron-positron ($e^\pm$) plasmas. We have performed simulations of "global" jets containing helical magnetic fields in order to examine how helical magnetic fields affect kinetic instabilities such as the Weibel instability, the kinetic Kelvin-Helmholtz instability (kKHI) and the Mushroom instability (MI). We have found that these kinetic instabilities are suppressed and new types of instabilities can grow. For the $e^- - p^+$ jet, recollimation-like instability occurs and jet electrons are strongly perturbed, whereas for the $e^\pm$ jet, a recollimation-like instability occurs at early times followed by a kinetic instability and the general structure is similar to a simulation without helical magnetic field. We need to perform further simulations using much larger systems to confirm these new findings.

On the role and morphology of magnetic field during flares in blazars

14 Sept
9:30
Contributed

Sunil Chandra

Tata Institute of Fundamental Research, India

The Active Galactic Nuclei (AGN) are well known to host an accreting supermassive black hole at the center of these systems, which powers the entire system through the conversion of gravitational potential energy to the radiation. The central region in these systems are obvious place to look for extreme physics at work. Blazars, a subclass of AGN, provide an unique opportunity to investigate the undergoing physical processes because these system posses a relativistic jet of plasma seen at very small angles to our line of sight. The central engine of even the nearest AGN is almost unresolvable so only the observables like lightcurve, spectra and polarization can serve us as a tool. The flux variability and modelling of spectral energy distribution (SED) are used as the diagnosis tools for the physical processes, the nature of particle energy distribution, the demographical information about jet and

emission region etc., responsible for unprecedented flares as frequently seen in blazars. Since last decade the polarimetric observations became possible over a range of frequencies and hence can provide very crucial information of magnetic field and emission processes in uniques way. Also the advancements in theoretical understanding of these objects led us to perform a very detailed time dependent modeling of simultaneous observations of flux polarization and spectral energy distribution. IBL S5 0716+714 was observed to be in brightest ever state in January 2015. We have performed a detail modelling of simultaneous light curve, SED and polarization to derive the topology of magnetic field in the emission region. The Role of magnetic reconnections are also indicated. A very detailed work will be discusse in the meeting.

Magnetic AGN luminosities and ultra high energy cosmic ray luminosities

14 Sept
9:45
Contributed

Carlos Coimbra-Araújo and Rita Anjos
Universidade Federal do Paraná, Brazil

We investigate the production of magnetic flux from rotating black holes in active galactic nuclei (AGNs) and compare it with the upper limit of ultra high energy cosmic ray (UHECR) luminosities, calculated from observed integral flux of GeV-TeV gamma rays for nine UHECR AGN sources. We find that, for the expected range of black hole rotations ($0.44 < a < 0.80$), the corresponding bounds of theoretical magnetic luminosities from AGNs coincides with the calculated UHECR luminosity. We argue that such result possibly can contribute to constrain AGN magnetic and dynamic properties as phenomenological tools to explain the requisite conditions to proper accelerate the highest energy cosmic rays.

The Energetic Particle Population in Centaurus A

14 Sept
10:00
Contributed

Paula Chadwick[1], Anthony Brown[1], Celine Boehm[1], Jamie Graham[1], Thomas Lacroix[2] and Joseph Silk[3]

[1]University of Durham, UK; [2]LAPTH Universite de Savoie, France; [3]Institut d'Astrophysique de Paris, France and Johns Hopkins University, USA

We report a significant hardening in the Fermi-LAT gamma-ray spectrum of the core of Cen A at E > 2.4 GeV, and evidence for variability below 2.4 GeV at the 99% confidence level. Taken together, these results support the hypothesis that, while the low energy component comes from the jet and is presumably leptonic in origin, an additional source of very high energy particles exists near the core of Cen A. We show that the observed gamma-ray spectrum is compatible with either a spike in the dark matter halo profile or a population of millisecond pulsars. A third possibility is the existence of a hadronic component from the jet. This work gives a strong indication of new gamma-ray production mechanisms in AGN and could even provide evidence for the clustering of heavy dark matter particles around black holes.

AGN STORM: A Leap Forward in Reverberation Mapping

14 Sept
10:35
Contributed

Bradley Peterson

The Ohio State University, USA

In 2014, we undertook the AGN Space Telescope and Optical Reverberation Mapping (AGN STORM) project, the largest ever AGN spectroscopic and photometric AGN monitoring program. The AGN STORM campaign was built around six months of daily UV spectroscopy of the well-studied Seyfert 1 galaxy NGC 5548 with the Cosmic Origins Spectrograph on Hubble Space Telescope. These observations were complemented by observations with Swift, Chandra, and Spitzer and a broad network of ground-based facilities, all resulting in high-quality well-sampled multiwavelength continuum and broad emission-line light curves. The observations have already yielded a number of surprises, including measurement of the size and temperature gradient of the accretion disk. The geometry of the broad-line region is found to be

complex and evolving. I will report on progress we have made in understanding the results of this program and on its potential implications for future reverberation-mapping campaigns.

Studying the outskirts of reverberation mapped AGNs

14 Sept
10:50
Contributed

Shai Kaspi

Tel Aviv University, Israel

About 100 AGNs have their black hole mass measured directly using the reverberation mapping technique over the past few decades. By now we have high enough numbers to explore unique subsamples within these objects and to study phenomenons across variety of AGNs. I will review recent reverberation mapping studies which focus on high-redshift high-luminosity AGNs and on AGNs with super-Eddington accreting massive black holes. These studies enable to investigate the BLR size, mass, and luminosity relations in different subsamples of AGNs and to check whether there are differences in these relations in different types of AGNs. In particular I will discuss the following questions: Is the BLR size - luminosity relation the same over the whole AGNs luminosity range? Are there different relations for different types of AGNs? What are these studies teaching us about theory of accretion into black holes in AGNs?

Searching for pairs of accreting supermassive black holes

14 Sept
11:05
Contributed

Krisztina Gabanyi[1], Sandor Frey[1], Stefanie Komossa[2], Zsolt Paragi[3] and Tao An[4]

[1]FOMI, Satellite Geodetic Observatory, Hungary; [2]Max-Planck-Institut fur Radioastronomie, Germany; [3]Joint Institute for VLBI ERIC, the Netherlands; [4]Shanghai Astronomical Observatory Chinese Academy of Sciences, China

In hierarchical structure formation scenarios, merging galaxies are expected to be seen in different phases of their coalescence. Simulations suggest that simultaneous activity of the supermassive black holes

(SMBHs) in the centers of the merging galaxies may be expected at kpc-scale separations. Currently, there are no direct observational methods which allow the selection or the confirmation of a large number of such dual active galactic nuclei (AGN) candidates. Several attempts were made to better understand the nature of double-peaked narrow emission line sources, and to differentiate the objects where the emission lines originate from narrow-line kinematics or jet-driven outflows from those where a pair of AGN can be responsible for the emission features. SDSS J1425+3231 was reported as a promising candidate based upon its double-peaked narrow [O III] optical emission lines. Our European VLBI Network (EVN) observation at 1.7 GHz showed two compact features separated by 2.6 kpc projected distance. Their high brightness temperatures indicate synchrotron origin of the radio emission in both components. Our sensitive e-MERLIN observation at 1.7 GHz revealed that the source has a core-jet structure, extended emission was revealed between the VLBI features. At 5 GHz, only the brighter component was detected by e-MERLIN. Thus, according to our radio interferometric observations, the double-peaked optical emission lines in SDSS J1425+3231 are most likely not caused by a pair of accreting SMBHs but can be better explained with jet-cloud interactions.

A statistical method for detecting gravitational recoils of supermassive black holes in active galactic nuclei

14 Sept
11:20
Contributed

Peter Raffai[1], Zoltan Haiman[2] and Zsolt Frei[1]

[1]Lorand Eotvos University, Hungary; [2]Columbia University in the City of New York, USA

We propose an observational test for gravitationally recoiling supermassive black holes in active galactic nuclei, based on a positive correlation between the velocities of black holes relative to their host galaxies, and their obscuring dust column densities, both measured along the line of sight. Black holes with recoil velocities comparable to the escape velocity from the galactic centre remain bound to the nucleus, and do not fully settle back to the centre of the torus due to dynamical friction in a typical quasar lifetime. By simulating 250,000 random observations of recoiling quasars, we find that for a subset of quasars obscured by dust tori in galactic centres, sample correlation coefficients can be as

high as r=0.28+/-0.02. Allowing for random +/-100 km/s errors in the line-of-sight velocities unrelated to the recoil dilutes the correlation for the quasars to $\sim$ 1/10th of this level. We conclude that a random sample of a few thousand obscured quasars could allow rejection of the no-correlation hypothesis with 3 sigma significance 95% of the time. Finally, we find that the fraction of obscured quasars decreases with the black hole velocity from $\sim$0.8 to $\sim$0.4. This predicted trend can be compared to the observed fraction of type II quasars, and can further test combinations of recoil, trajectory, and dust torus models.

The critical role of Gigahertz Peak Spectrum and Compact Steep Spectrum radio sources in AGN feedback

14 Sept
11:35
Contributed

Geoffrey Bicknell[1], Dipanjan Mukherjee[1], Alex Wagner[2] and Ralph Sutherland[1]

[1]Research School of Astronomy & Astrophysics, Australian National University, Australia; [2]Center for Computational Sciences, University of Tsukuba, Japan

There are a number of observational and theoretical investigations being carried out on the role of relativistic jets in radio galaxies in defining the characteristics of AGN feedback. The leads naturally to a focus on the role of Gigahertz Peak Spectrum (GPS) and Compact Steep Spectrum (CSS) sources, which are generally believed either to be an early phase in the evolution of radio galaxies or to be frustrated by their interaction with the interstellar medium (ISM) of the host galaxy. As part of our modelling of the interaction of relativistic jets with the inhomogeneous medium of elliptical galaxies, we have calculated the time evolution of the radio spectra of the emerging radio galaxy subject to free-free absorption by the partially ionized ISM. As a result of the fractal structure of the ISM, the low frequency spectrum of the radio source is not abruptly truncated but has a broad shape, similar to a rising power law. An interesting feature of the low frequency spectrum is that it becomes flatter at late times, as a result of the increasing turbulence in the ISM. Another feature of our models is that they are consistent with the well-established anti-correlation between turnover frequency and size of GPS/CSS sources. Our models show that the spectra of GPS and CSS sources may be utilized to understand the structure of the ISM in galaxies in their feedback phase.

Simulation of AGN feedback

14 Sept
11:50
Contributed

Martin Bourne

IoA/KICC, University of Cambridge, UK

Feedback from accreting supermassive black holes takes many forms, each of which is expected to play a key role in shaping the co-evolution of black holes and their host galaxies. However, a number of questions still remain. Quasar mode feedback, in the form of powerful accretion disc driven winds has been invoked to explain both observed scaling relations, such as the M-sigma relation, and large scale outflows with mass fluxes of hundreds to thousands of solar masses per year and momentum rates up-to $\sim$40 times the radiative output of the AGN. A critical issue remaining in understanding how these winds couple to and affect the host galaxy is whether or not they are in the momentum or energy conserving regime. To this end I will present potential observational signatures that could be used to distinguish between these regimes and also discuss the role of momentum and/or energy driven winds in establishing specific galaxy properties. Furthermore I will present the results of high resolution simulations exploring how such winds interact with a multi-phase ISM and hence highlight how the structural properties of the host galaxy can impact upon feedback efficiency. Finally, radio or maintenance mode feedback, in the form of highly collimated jets, is expected to prevent gas cooling onto the host galaxy and hence prevent further star formation once it has become "red and dead". I will present new numerical models of jet feedback using the moving mesh code AREPO and outline how such jets affect the physical properties of galaxy clusters, comparing results to both analytical models and observations.

AGN duty cycles in the Illustris simulation

14 Sept
12:05
Contributed

Colin DeGraf and Debora Sijacki
Institute of Astronomy, University of Cambridge, UK

One of the most important ways of studying the accretion onto supermassive black holes (and the feedback associated with it) is through the duty cycle of the black hole. Using the high-resolution cosmological simulation Illustris, I will discuss the evolution of black hole duty cycle with redshift, and its dependence on black hole mass, luminosity and host halo mass. In addition to the basic black hole duty cycle, I show how the halo duty cycle (for halos hosting luminous AGN) and duty cycles estimated from AGN clustering can significantly over-estimate black hole activity, especially at low-redshift, due to the contributions from satellite black holes which are often neglected. Finally, I will discuss the typical properties of the halos hosting these AGN, and the effect they have on activity rates.

Using cosmological simulations as a laboratory for the physics of AGN

14 Sept
12:20
Contributed

Lisa K. Steinborn and Klaus Dolag
Universitäts-Sternwarte, LMU München, Germany

The Magneticum Pathfinder Simulations are hydrodynamic cosmological simulations based on the TreePM-SPH code P-GADGET3. For these simulations we use an advanced sub-grid model for the accretion onto black holes (BHs), their associated active galactic nucleus (AGN) feedback, and for the dynamics of BHs. The simulations thus produce a realistic population of AGN, e.g. concerning their large-scale distribution, the AGN luminosity functions and the BH mass functions, providing us a laboratory for testing the physics of AGN, also beyond what can be seen in observations. On the one side we perform several test-runs to improve the AGN model. In particular, we are interested in different feedback mechanisms, such as radiative and mechanical feedback, or different accretion models. On the other side, large simulations with both a high resolution and a large volume produce an extremely large sample of AGN, which we use for example to study AGN trigger mechanisms like galaxy mergers, the connection to star formation activity and the origin and properties of dual and offset

AGN. Furthermore, we make predictions for large-scale AGN clustering measurements, where we employ the effect of different selection criteria. We find that AGN cluster less strongly than galaxies, indicating that AGN activity is not just a random event, but driven by the properties of their host galaxies and their environment. Our simulations predict a lack of AGN in galaxy groups, while galaxy clusters in general host radio-mode AGN and field galaxies mostly host quasar-mode AGN. The necessity of these two different modes infers the existence of different AGN types, being in conflict with a unified AGN model, since the different AGN types are driven by different accretion mechanisms, given by a different gas supply, and since they comprise different feedback mechanisms.

Posters

Optical variability patterns of RQ and RL quasars

Poster 16

Edi Bon[1], Paola Marziani[2], Nataša Bon[1], Ascensión del Olmo[3] and Jack Sulentic[3]

[1]Astronomical Observatory, Belgrade, Serbia; [2]INAF, Italy; [3]Instituto de Astrofisica de Andalucia (CSIC), Granada, Spain

We analyzed the light curves of several RQ and RL quasars belonging to the same parameter space volume in the 4D eigenvector 1 quasar sequence, using data from the Catalina Real-Time Transient Survey. We report preliminary results on detected variability pattern, and discuss possible mechanisms.

MAGIC detection of sub-TEV emission from gravitationally lensed blazar QSO B0218+357

Poster 17

Dijana Dominis Prester[1], J. Beccerra, S. Buson, E. Lindfors, M. Manganaro, D. Mazin, M. Nievas, K. Nilsson, J. Sitarek, A. Stamerra, F. Tavecchio, and Ie. Vovk for the MAGIC collaboration

[1]University of Rijeka - Department of physics, Croatia

The blazar QSO B0218+357 is the first gravitationally lensed blazar detected in the very high energy (VHE) gamma-ray spectral range. It is gravitationally lensed by the intervening galaxy B0218+357G (z=0.68), which splits the blazar emission into two components, spatially indistinguishable by gamma-ray instruments, but separated by a 10-12 days delay.

In July 2014 a flare from QSO B0218+357 was observed by the Fermi-LAT, and followed-up by the MAGIC telescopes during the expected time of arrival of the delayed component of the emission. The MAGIC and Fermi-LAT observations were accompanied by optical data from KVA telescope and X-ray observations by Swift-XRT, allowing us to construct the blazar broadband spectral energy distribution and extract some physical parameters.

QSO B0218+357 is one of the two most distant AGN (z=0.94) detected so far in the VHE gamma-ray range, together with PKS 1441+25 which was also detected by the MAGIC telescopes. The GeV and sub-TeV

data, obtained by Fermi-LAT and MAGIC, are used to set some constraints on the extragalactic background light that are compatible with current models.

The effect of AGN feedback on Sunyaev-Zeldovich properties of simulated galaxy clusters

Poster 18

Dunja Fabjan[1], Susanna Planelles[2], Stefano Borgani[3], Giuseppe Murante[4], Elena Rasia[5], Veronica Biffi[6], Nhut Truong[7], Cinthia Ragone-Figueroa[8], Gian Luigi Granato[4], Klaus Dolag[9], Elena Pierpaoli[10], Alexander M. Beck[9], Lisa K. Steinborn[9] and Massimo Gaspari[11]

[1]Faculty of Mathematics and Physics, University of Ljubljana, Slovenija; [2]Departamento de Astronomía y Astrofisica, Universidad de Valencia, Spain; [3]Astronomy Unit, Department of Physics, University of Trieste, Italy; [4]INAF - Osservatorio Astronomico di Trieste, Italy; [5]Department of Physics, University of Michigan, USA; [6]INAF - Osservatorio Astronomico di Trieste, Italy; [7]Dipartimento di Fisica, Università di Roma Tor Vergata, Italy; [8]IATE, CONICET, Observatorio Astronómico, Universidad Nacional de Córdoba, Argentina; [9]University Observatory Munich, Germany;[10]University of Southern California, USA; [11]Department of Astrophysical Sciences, Princeton University, USA

We studied the imprints that feedback from Active Galactic Nuclei (AGN) leaves on the intracluster plasma during the assembly history of galaxy clusters. To this purpose we used state-of-the-art cosmological hydrodinamical simulations based on an updated version of the TreePMSPH GADGET-3 code, comparing three sets of simulations with different prescriptions for the physics of baryons (including AGN and/or stellar feedback). We explore the effect of these different physics, in particular AGN feedback, on Intracluster medium properties observed via Sunyaev-Zel'dovich (SZ) effect using an extended set of galaxy clusters (140 clusters with masses above 5×10^{13} $M_{\odot}/h$). Some of the main findings are that the scaling relation between the integrated SZ flux and the galaxy cluster mass is in good accordance with several observed samples, especially for massive clusters, and does not show any clear redshift evolution, with the slope of the relation close to the theoretical one in the AGN feedback case. As for the scatter of this relation, we obtain a mild dependence on the cluster dynamical state.

Empirical Multi wavelength prediction method for Very High Energy Gamma-ray emitting BL Lacs

Poster 19

Vandad Fallah Ramazani[1], Elina Lindfors[1] and Kari Nilsson[2]

[1]University of Turku, Finland; [2]FINCA, Finland

The majority of extragalactic objects detected in Very High Energy (VHE) γ-ray band (¿100 GeV) are from rare type of radio-loud Active Galactic Nuclei, called BL Lacs. In this work, we present the most up-to-date and complete multi-wavelength correlation analysis on spectral and luminosity properties of VHE γ-ray emitting (TeV) BL Lacs. We have performed a first detailed analysis of the radio and optical variability of the northern hemisphere TeV BL Lacs, which reveal common long term variability patterns. We use the derived correlations to construct a prediction method. In my talk, I will present the statistical approach, which uses lower frequency characteristics of BL Lacs, to predict VHE γ-ray emission. We will provide a list of promising BL Lacs to be observed by Imaging Air Cherenkov Telescopes.

Open our eyes to wider fields in VLBI surveys

Poster 20

Sandor Frey[1] and Kristof Rozgonyi[2]

[1]Institute of Geodesy, Cartography and Remote Sensing, Hungary; [2]Eotvos Lorand University, Hungary

The innermost pc-scale structure of radio-loud active galactic nuclei (AGN) can be directly studied with the technique of very long baseline interferometry (VLBI). High-resolution VLBI imaging observations reveal the geometry and the physical properties of relativistic jets emanating from the vicinity of the accreting central supermassive black holes. VLBI surveys allow us to conduct statistical investigations of large source samples, and also to discover new phenomena or types of objects. High-quality VLBI imaging of hundreds or thousands of radio sources is an observationally and computationally intensive task. Moreover, the compact radio jet structure in AGN is usually confined to the central region of tens of milli-arcseconds (mas). The VLBI technique does not allow imaging with an undistorted field of view larger than typically a few arcseconds at cm wavelengths. However, for practical reasons, often a much smaller fraction of the field, the central region is imaged only. Here we introduce an automated imaging process

and present its application to the publicly available calibrated visibility data of a prominent VLBI survey. We imaged the $\sim$ 1.5-arcsec radius fields around more than 1000 radio sources, and found a variety of radio structures that extend to 100-mas scales in a small subset of the sample. Some of them were missed in the original survey and are yet unknown in the literature. We also give possible interpretations of these structures.

Observations of possible jet formation in the binary blazar OJ287

Poster 21

H. Jermak[1], I. A. Steele[2], G. P. Lamb[2], M. Valtonen[3], S. Zola[4], T. Hovatta[5,6] and OJ287 15-16 collab.[7]

[1]Lancaster University, UK; [2]Liverpool John Moores University, UK; [3]University of Turku, Finland; [4]Jagiellonian University, Poland; [5]Aalto University Metsahovi Radio Observatory, Finland. Aalto University Department of Radio Science and Engineering, Finland; [6]Finnish Center for Astrophysics with ESO, University of Turku, Finland; [7]See Valtonen et al. 2016

In November- December 2015 the OJ287 binary supermassive black holes system under went a double peaked flare associated with the interaction of the secondary supermassive black hole with the accretion disk of the primary supermassive black hole causing a predicted flare in optical wavelengths (see Valtonen et al. ApJ letters, 819:L37, 2016 March). 20 days after the first flare, a second flare was observed, this was joined by a simultaneous optical degree of polarisation flare- the highest on record - reaching 43%. This first flare, with its low polarisation, is likely to be dominated by thermal emission which dilutes the non-thermal polarisation emission. The second flare is dominated by non-thermal emission. Here the possible causes of the two flares are discussed.

Highly accreting quasars at high redshift: a tool for cosmology

Poster 22

Paola Marziani[1], Mary Loli Martínez-Aldama[2], Ascension del Olmo[2], Jack Sulentic[2], Jaime Perea[2], Deborah Dultzin[3], Alenka Negrete[4], Mauro DOnofrio[5], Edi Bon[6] and Nataša Bon[6]

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Highly accreting quasars have the remarkable property that their Eddington ratio is expected to saturate toward values of order unity, making them possible cosmological probes. Using optical/UV spectral line widths and ratios we are able not only to estimate black hole masses and Eddington ratios avoiding the use of scaling laws, but also to estimate redshift-independent source luminosities. We present first results from the analysis of a sample of 50 type I highly accreting quasars (radiating at Eddington ratio close to unity) at redshift between 2 and 4 that were identified using the 4D Eigenvector 1 formalism of Sulentic et al. (2000). The new data, coupled with survey spectra, make it possible to discuss the relation between their accretion properties and UV parameters, to explore to which extent these properties could serve as a redshift-independent distance indicator, and to obtain an estimate of the cosmic matter density parameter $\Omega_{\rm M}$.

Ensemble quasar spectral variability from the XMM-Newton serendipitous source catalogue

Poster 23

Roberto Serafinelli and Fausto Vagnetti

University of Rome 'Tor Vergata', Italy

Variations of the X-ray spectral slope have been found in many Active Galactic Nuclei (AGN) at moderate luminosities and redshifts, typically showing a "softer when brighter" behaviour. However a similar study has never been done for high-luminosity AGNs. We present an analysis of the spectral variability based on a large sample of quasars, in wide intervals of luminosity and redshift, measured at several different epochs, extracted from the latest release of the XMM-Newton Serendipitous Source Catalogue. Our analysis confirms a "softer when brighter" trend also for our sample, extending to high luminosity and

redshift the general behaviour previously found. These results can be understood in the light of current spectral models, such as intrinsic variations of the X-ray primary radiation, or superposition with a constant reflection component.

Peculiar emission from the new VHE gamma-ray source H1722+119

Poster 24

Tomislav Terzić[1], Antonio Stamerra[2] (for the MAGIC Collaboration), Filippo D'Ammando[3,4](for the Fermi-LAT Collaboration), Claudia M. Raiteri[5], Massimo Villata[5], Francesco Verrecchia[6,7], Talvikki Hovatta[8,9], Walter Max-Moerbeck[10], Anthony C. S. Readhead[9], Riho Reinthal[11] and Joseph L. Richards[12]

[1]University of Rijeka, Department of Physics, Croatia; [2]INAF National Institute for Astrophysics, Italy; [3]Dip. Di Fisica e Astronomia, Universita degli Studi di Bologna, Italy; [4]INAF - Istituto di Radioastronomia, Italy; [5]INAF - Osservatorio Astrofisico di Torino, Italy; [6]INAF - Osservatorio Astronomico di Roma, Italy; [7]ASI Science Data Center (ASDC), Italy; [8]Aalto University Metsahovi Radio Observatory, Finland; [9]Cahill Center for Astronomy and Astrophysics, California Institute of Technology, USA; [10]National Radio Astronomy Observatory, USA; [11]Tuorla Observatory, Department of Physics and Astronomy, University of Turku, Finland; [12]Department of Physics, Purdue University, USA

The BL Lac object H1722+119 was observed in the very-high energy band (VHE, 100 GeV) by the MAGIC (Major Atmospheric Gamma-ray Imaging Cherenkov) telescopes between 2013 May 17 and 22, following a state of high activity in the optical band measured by the KVA (Kungliga Vetenskapsakademien) telescope. Integrating 12.5 h of observation, the source was detected with a statistical significance of 5.9 sigma, corresponding to (2.0 ± 0.5) per cent of the Crab Nebula flux above 150 GeV. Contemporaneous observations were performed by the the LAT (Large Area Telescope) on board the Fermi satellite in the high energy range (HE, 100 MeV r to be z = 0.34 ± 0.15. No significant temporal variability of the flux in the HE and VHE bands was found. Contemporaneous data from the KVA and the OVRO telescopes show variable flux in optical and radio wavebands, respectively, although with different patterns.

Equilibrium configurations of rotating magnetized self-gravitating tori - influence of self-gravity and the organized magnetic field

Poster 25

Audrey Trova

Astronomical Institute of the Academy of Sciences, Czech Republic

We present a self-consistent field method to study equilibrium configurations of magnetized rotating self-gravitating gaseous tori in the context of AGN. The rotating torus is modeled by a perfect fluid with barotropic equation of state, is embedded in a spherical gravitational and dipolar magnetic fields. Their vertical and radial structure is influenced by the balance between the gravitational and the magnetic force. First, we will show that the self-gravity and the magnetic field produced by the charged torus can have an impact on the morphology of the solutions and on the one-ring sequence. Secondly, the existence of the solutions is possible for certain values of the model parameters, such as the rotation law, the polytropic index and the magnetic field intensity.

Topic 5: Tests of fundamental theories of physics using black hole systems

How to measure black holes: numerical relativity and gravitational waves

15 Sept
9:00
Invited

Mark Hannam

Cardiff University, UK

Gravitational waves have been directly detected for the first time, from the collision of two black holes. Measuring the properties of the black holes (their masses and spins) required theoretical models of the signal, calculated by combining analytic approximation techniques with numerical solutions of the full Einstein equations for the last orbits and merger. I will discuss how the models were produced that were used in measuring the properties of the first black-hole-binary ever observed, and the challenges ahead as we enter the era of gravitational wave astronomy.

Electromagnetic follow-up of gravitational wave candidates

15 Sept
9:30
Solicited

Silvia Piranomonte[1], Enzo Brocato[1], Marica Branchesi[2], Sergio Campana[3], Stefano Covino[3], Enrico Cappellaro[4], Eliana Palazzi[5], Elena Pian[5] and Aniello Grado [6] on behalf of the GRAWITA project

[1]INAF - Osservatorio Astronomico di Roma, Italy; [2]Università degli studi di Urbino, Italy; [3]INAF - Osservatorio Astronomico di Brera, Italy; [4]INAF - Osservatorio Astronomico di Padova, Italy; [5]INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica, Italy; [6]INAF - Osservatorio Astronomico di Capodimonte, Italy

The Advanced LIGO detectors on September 14th, for the first time, detected a binary black hole merger (GW150914) for which a detectable electromagnetic counterpart is little expected. This detection showed that EM follow-up facilities are able to react quickly to GW signals covering radio, optical, near-infrared, X-ray, and gamma-ray wavelengths with ground- and space-based over the entire gravitational sky localization even if they have to deal with large position uncertainties up to hundreds square degrees. Therefore wide-field cameras and rapid

follow-up observations are crucial to characterize the EM candidates and the first EM counterpart identification. For this reason, it will be important to enhance the interdisciplinary exchange of know-how and the european collaboration between the worldwide community related to the multi-messenger astronomy.
In this talk I want to present the activities we are currently currying on in order to optimize the response of the GRAWITA facilities network to the expected GW triggers together with our first results related to the signal GW150914. The GRAWITA project is representing an efficient operational framework capable of fast reaction on large error box triggers and direct identification and characterization of the candidates. All the activities we will describe are expect to provide means and opportunities to the Italian and European astronomical communities to have a leading role in the GW astronomy and Time Domain Astronomy fields.

Spectroscopic Follow-up of Candidate Electromagnetic Counterparts of Gravitational Wave Sources

15 Sept
9:55
Contributed

Iain A. Steele and Christopher M. Copperwheat
Liverpool John Moores University, UK

The first direct detection of gravitational waves was made in late 2015 with the Advanced LIGO detectors. By prior arrangement, a worldwide collaboration of electromagnetic follow-up observers were notified of candidate gravitational wave events during the first science run, and many facilities were engaged in the search for counterparts. No counterparts were identified, which is in line with expectations given that the events were classified as black hole - black hole mergers. However these searches laid the foundation for similar follow-up campaigns in future gravitational wave detector science runs, in which the detection of neutron star merger events with observable electromagnetic counterparts is much more likely. Three alerts were issued to the electromagnetic collaboration over the course of the first science run, which lasted from September 2015 to January 2016. Two of these alerts were associated with the gravitational wave events since named GW150914 and GW151226. In this paper we provide an overview of the Liverpool Telescope contribution to the follow-up campaign over this period. Given

the hundreds of square degree uncertainty in the sky position of any gravitational wave event, efficient searching for candidate counterparts required survey telescopes with large (degrees) fields-of-view. The role of the Liverpool Telescope was to provide follow-up classification spectroscopy of any candidates. We followed candidates associated with all three alerts, observing 1, 9 and 17 candidates respectively. We classify the majority of the transients we observed as supernovae.

MAGIC electromagnetic follow-up of Gravitational Wave alerts

15 Sept
10:10
Contributed

Barbara De Lotto[1,2], Angelo Antonelli[3], Alessio Berti[2,4], Alessandro Carosi[3] and Antonio Stamerra[5,6]

[1]University of Udine, Italy; [2]INFN-Trieste, Italy; [3]INAF Rome, Italy; [4]University of Trieste, Italy; [5]INAF, Italy; [6]SNS Pisa, Italy

The MAGIC two 17m diameter Cherenkov telescope system joined since 2014 the electromagnetic follow-up of LIGO-Virgo gravitational waves (GW) alert community. During the 2015 O1 LIGO-Virgo science run, which witnessed the first observation of GWs from a binary black hole merger, we set up the procedure for GW alerts follow-up and took data following the last GW alert. MAGIC results on the data analysis and prospects for the forthcoming 2016 O2 run will be presented.

On the gamma-ray burst-gravitational wave association in GW150914

15 Sept
10:45
Contributed

Agnieszka Janiuk[1], Michal Bejger[2], Szymon Charzynski[1] and Petra Sukova[1]

[1]Center for Theoretical Physics PAS, Poland; [2]Copernicus Astronomical Center, PAS, Poland

The data from the Fermi Gamma-ray Burst Monitor (GBM) satellite suggest that the recently discovered gravitational wave source, a pair of two coalescing black holes, was related to a gamma-ray burst. The electromagnetic radiation in high energy (above 50 keV) originated from a weak transient source and lasted for about 1 second. Its localization is consistent with the direction to GW150914. We speculate on the

possible scenario for the formation of a gamma-ray burst accompanied by the GW signal. Our model invokes a close binary system consisting of a massive star and a black hole, which leads to triggering of a collapse of the star's nucleus, formation of a second black hole, and finally to the binary black hole merger. For the most-likely configuration of the binary spin vectors with respect to the orbital angular momentum in the GW150914 event, the recoil velocity acquired by the final black hole through gravitational waves emission allows it to take only a small fraction of matter from the host star. The gamma-ray burst is produced on the cost of accretion of this remnant matter onto the final black hole. The moderate spin of the final black hole accounts for the gamma-ray burst jet to be powered by a weak neutrino emission rather than the Blandford-Znajek mechanism, and hence explains low power available for the observed GRB signal.

Search for UHE neutrinos in coincidence with LIGO GW150914 event with the Pierre Auger Observatory

15 Sept
11:00
Contributed

Lili Yang for the Pierre Auger Collaboration

University of Nova Gorica, Slovenia

The first gravitational wave transient GW150914 was detected by Advanced LIGO on Sept. 14th, 2015 at 09:50:45 UTC. In addition to follow-up electromagnetic observations, the detection of neutrinos will probe deeply and more on the nature of astrophysical sources, especially in the ultra-high energy regime. Neutrinos in the EeV energy range were searched in data collected at the surface detector of the Pierre Auger Observatory within +/- 500 s and 1 day after the GW150914 event. No neutrino candidates were found. Based on this non-observation, we derive the first and only one neutrino fluence upper limit at EeV energies for this event at 90% CL, and report constraints on existence of accretion disk around mergers.

What was the Initial Mass of Merging Black Holes in GW150914?

15 Sept
11:15
Contributed

Hiromichi Tagawa[1] and Masayuki Umemura[2]

[1]University of Tokyo, Japan; [2]Center for Computational Sciences, University of Tsukuba, Japan

Very recently, the Laser Interferometer Gravitational-Wave Observatory (LIGO) has detected the gravitational wave (GW) event,GW150914, as a result of the merger of a $\sim$30 $M_{\rm Sun}$ black hole (BH) binary (Abbott et al. 2016a). If BHs with $\sim$ 30 $M_{\rm Sun}$ had been generated as stellar remnants, massive progenitor stars should have taken weak stellar winds. This implies that the progenitor stars formed in a lower metallicity environment (Abbott et al. 2016b), possibly being Pop III stars. If a BH binary of about 30 $M_{\rm Sun}$ merges solely by the GW radiation, the binary separation should be smaller than 1 AU. However, in our recent studies, we have found that multiple BHs of about 30 $M_{\rm Sun}$ can merge with each other under the gas-rich environments through the dynamical friction by gas. In this case, a considerable amount of gas can accrete onto BHs before the merger, that is, the initial mass of BHs can be smaller than 30 $M_{\rm Sun}$. To explore this possibility, we have performed post-Newtonian N-body simulations on mergers of accreting stellar-mass BHs. The simulations properly incorporate such general relativistic effects as the pericentre shift and gravitational wave emission as well as the gas dynamical friction and the mass accretion. Based on these simulations, we find that the BH merger in GW150914 is likely to be accompanied by several $M_{\rm Sun}$ of gas accretion.

A new route towards merging massive black holes

15 Sept
11:30
Contributed

Pablo Marchant[1], Norbert Langer[1], Philipp Podsiadlowski[2], Thomas Tauris[1] and Takashi Moriya[3]

[1]Argelander Institut für Astronomie, Universität Bonn, Germany; [2]Department of Astrophysics, University of Oxford, UK; [3]National Astronomical Observatory of Japan, Japan

With recent advances in gravitational-wave astronomy, the direct detection of gravitational waves from the merger of two stellar-mass compact objects has become a realistic prospect. Evolutionary scenarios towards mergers of various double compact objects generally invoke so-called

common-envelope evolution, which is poorly understood and leads to large uncertainties in the predicted merger rates. Here we explore, as an alternative, the scenario of massive overcontact binary (MOB) evolution, which involves two very massive stars in a very tight binary that remain fully mixed as a result of their tidally induced high spin. While many of these systems merge early on, we find many MOBs that swap mass several times, but survive as a close binary until the stars collapse. The simplicity of the MOB scenario allows us to use the efficient public stellar-evolution code MESA to explore it systematically by means of detailed numerical calculations. We find that, at low metallicity, MOBs produce double-black-hole (BH+BH) systems that will merge within a Hubble time with mass-ratios close to one, in two mass ranges, about 25...60 $M_{\rm Sun}$ and $\gtrsim$130 $M_{\rm Sun}$, with pair-instability supernovae (PISNe) being produced at intermediate masses. Our models are also able to reproduce counterparts of various stages in the MOB scenario in the local Universe, providing direct support for the scenario. We map the initial binary parameter space that produces BH+BH mergers, determine the expected chirp mass distribution, merger times, and expected Kerr parameters, and predict event rates. We find typically one BH+BH merger event for $\sim$1000 core-collapse supernovae for $Z \lesssim Z_{\rm Sun}/10$. The advanced LIGO (aLIGO) detection rate is more uncertain and depends on the cosmic metallicity evolution. From deriving upper and lower limits from a local and a global approximation for the metallicity distribution of massive stars, we estimate aLIGO detection rates (at the aLIGO design limit) of $\sim 19 - 550$ yr^{-1} for BH-BH mergers below the PISN gap and of $\sim 2.1 - 370$ yr^{-1} above the PISN gap. Even with conservative assumptions, we find that aLIGO will probably soon detect BH+BH mergers from the MOB scenario. These could be the dominant source for aLIGO detections.

Binary black holes are formed in the dark

15 Sept
11:45
Solicited

Felix Mirabel

CEA, France & IAFE, Argentina

A binary black hole with components of 30-40 solar masses as the source of gravitational waves GW150914, can be formed from a binary of massive stars if both black holes are formed by direct collapse, namely, with no energetic supernova accompanied by large mass loss that would significantly reduce the mass of the compact objects, and in most cases unbind the binary system. Theoretical models set mass ranges for black hole formation by direct collapse, but until recently observational evidences had been elusive.

I will review the astrophysical strategies that are being used to gain observational insight on the formation of stellar black holes by direct collapse:
(1) the kinematics of black hole x-ray binaries to constrain putative natal supernova kicks imparted to black holes,
(2) the search for stellar progenitors of core-collapse supernovae in archived images of nearby galaxies to constraint the mass of the progenitors,
(3) the identification of massive stars that quietly disappear without optically bright supernovae,
(4) spectroscopy of the nebular emission of supernovae to constraint the mass of the progenitors by the presence and/or absence of nucleosynthetic products,
(5) the detection of gravitational waves produced by fusion of binary black holes.

From the observations it is concluded that black holes of $\sim$10 $M_\odot$ and lower masses may be formed by implosion of stars with > 18 $M_\odot$, and that a large fraction of massive stellar binaries of low metallicity in the universe end as binary black holes.

Unveiling the first black holes

15 Sept
14:00
Invited

Priyamvada Natarajan
Yale University, USA

I will review our current understanding of the formation, fueling and feedback from early black holes that form in the high redshift universe. In addition to discussing current theoretical models, I will also focus on the observational signatures of the competing models and how these are likely to help us discriminate between models.

Black holes in Einstein-Gauss-Bonnet-dilaton theory

15 Sept
14:30
Invited

Jutta Kunz
Carl von Ossietzky University, Germany

Generalizations of the Schwarzschild and Kerr black holes are discussed which include higher curvature corrections in the form of the Gauss-Bonnet term, which is coupled to a dilaton. The properties of these black holes are discussed and compared to those of black holes in General Relativity. The angular momentum of the EGBd black holes can slightly exceed the Kerr bound. For their innermost stable circular orbits the radius to mass ratio can e.g. deviate by 10% from the Kerr value, and their orbital by 60%. Also QNMs of EGBd black holes are discussed.

Black holes as probes of Lorenz Invariance Violations

15 Sept
15:00
Invited

Dimitrios Emmanoulopoulos
University of Southampton, UK

I start by giving a brief overview of the arguments motivating the presence of deformed relativistic symmetries in the quantum-gravity regime, and the rich phenomenological program which has tested this proposal over the last decade. I close by comparing this class of models with data recently announced by the IceCube neutrino telescope, showing that the present experimental situation is still inconclusive but preliminarily favors a new-physics scenario which can be based on Planck-scale-deformed relativistic symmetries.

Searching for ultra-light new particles with black hole superradiance

15 Sept
15:30
Invited

Robert Lasenby
Perimeter Institute for Theoretical Physics, Canada

Many theories of beyond-Standard-Model physics predict new particles with very small masses, and very weak couplings to ordinary matter. The QCD axion, proposed to explain the smallness of the neutrons electric dipole moment, is a prime example. Strong gravitational fields around spinning black holes provide a unique mechanism for producing such particles, relying only on their gravitational coupling. If there exists a new bosonic particle with Compton wavelength comparable to the size of a Kerr BH, then superradiance - an analogue of the Penrose process - will populate gravitationally-bound states around the BH. The occupation number of these states grows exponentially, spinning down the BH and forming a very-high-occupation-number bosonic cloud around it.
Both of these effects have observational implications. Measurements of BH spins in X-ray binaries and through gravitational waves can exclude or provide evidence for ultralight particles. In addition, the bosonic cloud would produce highly monochromatic gravitational radiation at frequencies within the LIGO band, giving a direct signature of a new particle. With advanced LIGO having just opened a window onto the

gravitational wave universe, such effects could be seen within the next few years.

Kerr black holes with scalar or Proca hair

15 Sept
16:20
Contributed

Carlos Herdeiro, Eugen Radu, Pedro Cunha and Helgi Runarsson
Aveiro University, Portugal

Over the last two years it has been found that new classes of asymptotically flat black hole solutions, regular on and outside the event horizon, bifurcating from the vacuum Kerr solution, exist in General Relativity, with simple matter contents that obey all energy conditions, namely Kerr black holes with scalar hair [1] and Proca hair [2]. In this talk I will review the general mechanism that allows these solutions to exist, intimately connected to superradiance triggered by ultra-light bosonic fields, how these solutions circumvent well known no-hair theorems and some of their phenomenology which can be considerably distinct from that of Kerr [3,4].

[1] C. A. R. Herdeiro, E. Radu, Phys.Rev.Lett. 112 (2014) 221101
[2] C. Herdeiro, E. Radu, H. Runarsson, arXiv:1603.02687 [gr-qc]
[3] C. Herdeiro, E. Radu, Class.Quant.Grav. 32 (2015) 14, 144001
[4] P. V. P. Cunha, et al. Phys.Rev.Lett. 115 (2015) 21, 211102

How might a black hole disappear?

15 Sept
16:35
Contributed

Saeede Nafooshe and Martin O'Loughlin
Trieste University, Italy

In this talk we will discuss the near-singularity region of the linear mass Vaidya metric. We investigate the behavior of the numerical solutions for the scattering of scalar and electromagnetic metric perturbations from the singularity. We observe that, around the total evaporation point, quasinormal-like oscillations appear, indicating that this may be an interesting model for the description of the end point of black hole evaporation.

QED in the background of evaporating black holes

15 Sept
16:50
Contributed

Viacheslav Emelyanov

Karlsruhe Institute of Technology, Germany

Far away from black holes, one might expect that quantum field quantization performed in Minkowski space is a good approximation. Indeed, all experimental tests in the particle colliders reveal no deviations so far. Nevertheless, black holes should leave imprints of their presence in quantum processes. In this talk, we shall discuss several imprints of small evaporating black holes in QED in the weak gravity regime.

A study on accretion of dark energy onto Morris-Thorne Wormhole and the consequences

15 Sept
17:05
Contributed

Surajit Chattopadhyay

Pailan College of Management and Technology, India

Wormholes may be classified into two categories : Euclidean wormholes and Lorentzian wormholes. The Euclidean wormholes arise in Euclidean quantum gravity and the Lorentzian wormholes, which are static spherically symmetric solutions of Einsteins general relativistic field equations. The Lorentzian wormhole consists of two asymptotically flat spacetimes and the bridge connecting two space-times. In general, the flatness of two spacetimes is not necessarily required for constructing wormholes. Morris-Thorne solution is the most important model of simplicity however is not the unique static solution. In this work, we have studied accretion of dark energy onto Morris-Thorne wormhole with three different forms, namely, holographic dark energy, holographic Ricci dark energy and modified holographic Ricci dark energy. Considering the scale factor in power-law form we have observed that as the dark energy accrets onto wormhole, the mass of the wormhole is decreasing. In the next phase we considered three parameterization schemes that are able to get hold of quintessence as well as phantom phases. Without any choice of scale factor we reconstructed Hubble parameter from conservation equation and dark energy densities and subsequently got the mass of the wormhole separately for accretion of the three dark energy candidates. It was observed that if these dark energies accrete onto the wormhole, then for quintessence

stage, wormhole mass decreases up to a certain finite value and then again increases to aggressively during phantom phase of the universe.

Posters

Optical properties of black holes in the presence of a plasma: The shadow

Poster 26

Farruh Atamurotov
Institute of nuclear physics, Uzbekistan

We have studied photon motion around axially symmetric rotating Kerr black holes in the presence of a plasma with radial power-law density. It is shown that in the presence of a plasma, the observed shape and size of the shadow changes depending on the (i) plasma parameters, (ii) black hole spin, and (iii) inclination angle between the observer plane and the axis of rotation of the black hole. In order to extract the pure effect of the plasma influence on the black hole image, the particular case of the Schwarzschild black hole has also been investigated and it has been shown that the photon sphere around the spherically symmetric black hole is left unchanged under the plasma influence; however, the Schwarzschild black hole shadow size in the plasma is reduced due to the refraction of the electromagnetic radiation in the plasma environment of the black hole.

Circular Motion and Polish Doughnuts in NUT spacetime

Poster 27

Pavel Jefremov and Volker Perlick
ZARM, University of Bremen, Germany

We investigate parameters of circular orbits in NUT spacetime and show that they lie not in the equatorial plane but in the surface given by an expression we derived in our work. Discussed are also possible influences of Manko-Ruiz constant on the parameters of motion. As a model illustrating possible observable features of NUT spacetime we consider the Polish Doughnuts model of accretion.

Applicability of the Ni's solution of Einstein field equations to the real objects

Poster 28

Lubos Neslusan

Astronomical Institute of the Slovak Academy of Sciences, Slovakia

In 2011, Chinese researcher Jun Ni published the result of his solution of the Einstein field equations for the spherically symmetric distribution of matter. These equations were the same as Oppenheimer and Volkoff (O) used in their famous classical work on neutron cores. However, in contrast to the O result, Ni obtained the solution, which enables a construction of relativistic compact object (RCO) of whatever large mass and its outer surface is always situated above the event horizon. The Ni's solution appears to be the super-class of the O's solution. The proofs of the maximum mass of stable RCO are valid only for the O subclass. In our talk, we discuss the main differences between both Ni's and classical O-subclass; solutions. In addition, we present a qualitative model for an object resembling a quasar with an extented, galactic-scale "corona". As well, we mention some potential observations, which could support or suppress the idea of applicability of the Ni's solution to the real RCOs.

Astronomical Observation Evidences of Existence of Magnetic Monopoles and No Black Hole at the GC

Poster 29

Qiuhe Peng

Nanjing University, China

Some key observations have been reported recent years. 1) An abnormally strong radial magnetic field near the GC is discovered in 2013 (Eatough et al., 2013). 2) Some radiation from the radio to the sub-mm wavelength band have been detected in the region (10-50) $R_{\rm g}$ of the GC, and a surprisingly weak X-ray emitted from the GC discovered by the Chandra and it is inferred as radiated from region $\leq 10R_{\rm g}$ due to the hour long timescale for some detected weak X-ray flare and small NIR flare. For the thermal radiation, the power peaking is around 10^{12} Hz in the sub mm band. (Falcke and Marko, 2013). Firstly, we demonstrate that the radiations observed from the region neighbor of the Galactic Center (GC) are hardly emitted by the gas of accretion disk which is prevented from approaching to the GC by the abnormally strong radial

magnetic field. These radiations can't be produced by the black hole at the Center. However, the dilemma of the black hole model at the GC be naturally solved in our model of supermassive object with magnetic monopoles (SMOMM, Peng and Chou 2001). Three predictions in our model are quantitatively in agreement with the observations:1) Plenty of positrons are produced from the direction of the GC with the rate is or so. This prediction is quantitatively confirmed by observation (Knodlseder et al., 2003); 2) The magnetic monopole condensed in the core region of the supermassive object can generate radial magnetic field. The magnetic field strength at the surface of the object is about 20-100 Gauss at $1.1 \times 10^4 R_{\rm s}$ ($R_{\rm s}$ is the Schwarzschild radius) or B≈(10-50) mG at r=0.12 pc. This prediction is quantitatively in agreement with the lower limit of the observed magnetic field (Eatough et al.2013); 3) The surface temperature of the super-massive object in the Galactic center is about 120 K and the corresponding spectrum peak of the thermal radiation is at 10^{13} Hz in the sub-mm wavelength regime. is quantitatively basically consistent with the recent observation (Falcke and Marko, 2013) on the quatitative. The Conclusions of the paper are: It could be an astronomical observational evidence of the existence of magnetic monopoles and no black hole is at the GC.

Topic 6: Technology drivers and future capabilities

Post-Newtonian-accurate SMBH dynamics in galactic-scale numerical simulations

15 Sept
17:20
Contributed

Antti Rantala[1], Pauli Pihajoki[1], Peter H. Johansson[1] and Thorsten Naab[2]

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Softening of the gravitational potential in cosmological and galactic-scale numerical simulations severely limits the modelling of the dynamics of supermassive black holes (SMBHs). We have developed a regularized integrator module KETJU to accurately solve the non-softened gravitational dynamics within the influence radius of SMBHs in the tree-gravity+hydrodynamics code Gadget-3. The module is based on the well-established Algorithmic Chain Regularization method and is an ideal tool for modelling SMBH systems in galaxies. We apply Post-Newtonian corrections up to order PN3.5, including optionally spin-dependent terms and the so-called cross-term corrections, as well as the gravitational wave emission at the SMBH coalescence. As a first application of our code we present new accurate SMBH merger timescales in high-resolution galaxy merger simulations. We also study the formation of cored elliptical galaxies via interactions of a SMBH binary with the surrounding stars during the late stages of a galaxy merger.

Photon and polarization transport in general spacetimes

15 Sept
17:35
Contributed

Pauli Pihajoki

University of Helsinki, Finland

I present a new computationally efficient and easily extensible C++ library for propagating geodesics in a curved spacetime, where the metric is arbitrary. The library can be used to find the path of geodesics, including intersections with arbitrary surfaces. It can also compute observer-dependent emission/absorption angles, gravitational and Doppler redshifts and the gravitational Faraday rotation of polarization. I will discuss methods to compute these effects numerically in the case of a general spacetime. Finally, I present applications of the code for modelling accreting black hole systems and pulse profiles of rapidly rotating neutron stars.

Acceleration of particles up to PeV energies at the galactic centre

16 Sept
9:00
Invited

Stefano Gabici

Université Paris Diderot, France

After a brief description of the HESS array of Cherenkov telescopes, I will report on recent very high energy observations of the galactic centre region which revealed the presence of a powerful PeVatron. This is the first of such objects detected, and its most plausible counterpart seems to be associated to Sgr A*, the supermassive black hole in the centre of our galaxy. Multiwavelength observations of the galactic centre region will also be discussed, in particular in the context of the problem of the origin of galactic cosmic rays.

Black hole astrophysics with the High Altitude Water Cherenkov gamma-ray observatory

16 Sept
9:30
Invited

Alberto Carramiñana for the HAWC collaboration
Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE), México

The High Altitude Water Cherenkov (HAWC) gamma-ray observatory is an extensive air shower array located in Sierra Negra, México, designed to monitor TeV emission from celestial sources. Located at an altitude of 4100 m and 19°N latitude, HAWC has a field of view of about 2 sr that is able to survey 2/3 of the sky every sidereal day. The 22,500 m^2 array started full science operations with its completion and inauguration on March 2015, with the ability to detect the Crab above 5σ in a single transit. HAWC observations of the blazars Mrk 421 and Mrk 501 are providing for the first time daily monitoring of these two AGN. We will report on these and on further results from black hole related observations.

Black Hole Astrophysics with the Cherenkov Telescope Array

16 Sept
10:00
Invited

Susumu Inoue[1], Andreas Zech[2], Daniel Mazin[3], Elina Lindfors[4], Jonathan Biteau [5], Tarek Hassan[6], Paul O'Brien [7], Jonathan Granot[8], Valerie Connaughton[9], Marc Ribo[10], Sera Markoff[11], Fabian Schussler[12], Elisa Bernardini[13], Michael Daniel[14] and Manuel Meyer[15]

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High-energy gamma rays provide critical insight into physical processes operating in various types of black holes in the Universe. They also offer new perspectives on issues in multi-messenger astronomy, observational cosmology and fundamental physics. Building on the knowledge gained so far from GeV-TeV observations and in synergy with concurrent facilities in other wavebands and channels, the next leap forward will be brought forth by the Cherenkov Telescope Array (CTA). CTA will operate as an open observatory and features the highest sensitivity and

angular resolution to date above ∼100 GeV, as well as broad energy coverage from ∼20 GeV up to 100 TeV and beyond. Comprehensive studies of spectra and variability for large numbers of active galactic nuclei will address outstanding questions concerning the mechanisms of radiation, particle acceleration and relativistic jet formation in supermassive black holes. Detections of gamma-ray bursts with high photon statistics are anticipated that will reveal their mysterious origin and clarify the role of stellar mass black holes in core collapse and/or compact binary merger events. Complementary information is expected from observations of targets not yet clearly detected at GeV-TeV, including tidal disruption events and Galactic black hole systems, as well as follow-up of high-energy neutrino and gravitational wave alerts. Finally, important contributions to related fields are foreseen, such as identification of the sources of ultrahigh energy cosmic rays, probes of intergalactic radiation and magnetic fields, and searches for Lorentz invariance violation and non-standard particles.

Search for neutrinos from black holes with IceCube

16 Sept
10:50
Invited

Kevin Meagher

Université libre de Bruxelles, Belgium

The IceCube Neutrino Observatory is a cubic kilometer neutrino telescope located at the Geographic South Pole. Cherenkov radiation emitted by charged secondary particles from neutrino interactions is observed by IceCube using an array of 5160 photomultiplier tubes embedded between 1.5-2.5 km deep in the Antarctic glacial ice. The detection of astrophysical neutrinos is IceCube's primary goal and has now been realized with the discovery of a diffuse, high-energy flux consisting of neutrino events from tens of TeV up to several PeV. Many analyses have been performed to identify the source of these neutrinos, correlations with active galactic nuclei, gamma-ray bursts, the galactic plane, as well as multi-messenger campaigns to alert other observatories of possible neutrino transients in real-time. However, the source of these neutrinos remains elusive, as no corresponding electromagnetic counterparts have been identified. This talk will give an overview of the detection principles of IceCube, the properties of the observed astrophysical neutrinos, the search for corresponding sources (including real-time searches), and plans for a next-generation neutrino detector, IceCube-Gen2.

X-ray polarimetry: a new window on black hole systems

16 Sept
11:20
Contributed

Rene Goosmann

Observatoire astronomique de Strasbourg, France

From the very beginning, black holes have been primary targets for X-ray astronomy. Important progress in our understanding of accreting black holes in active galactic nuclei or black hole X-ray binaries was made using X-ray spectroscopy and timing techniques. Nonetheless, certain enigmas remain unsolved and require to break degeneracies between different model scenarios. On behalf of the consortium behind the X-ray Imaging Polarimetry Explorer (XIPE) project, I am going to lay out the prospects of black hole research that are given by the new technique of X-ray polarimetry. The XIPE mission is currently under phase A study at the European Space Agency to be eventually selected for launch in 2025. Two other X-ray polarimetry satellite projects are being studied by NASA. Entirely dedicated to X-ray polarimetry these satellites would open up a brand new window on black hole systems. This is going to allow us, for instance, to explore strong gravity effects close to the event horizon of accreting stellar mass black holes or to put new constraints on the geometry and the optical depth of the corona in these systems. For the first time, we further can probe the magnetic field at the acceleration sites of extragalactic jets and finally decipher the true origin of their X-ray emission. Finally, An observatory like XIPE would unambiguously test if the supermassive black hole at the center of our Galaxy was a low-luminosity AGN a few hundred years ago and allow us to retrace the irradiation geometry in its environment.

LSST survey: millions and millions of quasars

16 Sept
11:50
Invited

Željko Ivezić
University of Washington, USA

The Large Synoptic Survey Telescope (LSST), the next-generation optical imaging survey sited at Cerro Pachon in Chile and starting in 2022, will provide hundreds of detections for a sample of more than ten million quasars with redshifts up to about seven. The LSST design, with an 8.4m (6.7m effective) primary mirror, a 9.6 sq. deg. field of view, and a 3.2 Gigapixel camera, will allow about 10,000 sq. deg. of sky to be covered twice per night, every three to four nights on average, with typical 5-sigma depth for point sources of r=24.5 (AB). With about 1000 observations in ugrizy bands over a 10-year period, these data will enable a deep stack reaching r=27.5 (about 5 magnitudes deeper than SDSS) and faint time-domain astronomy. The measured properties of newly discovered and known astrometric and photometric transients will be publicly reported within 60 sec after closing the shutter. After a brief introduction to LSST and a construction status report, I will review optical quasar selection techniques, with emphasis on methods based on colors, variability properties, and astrometric behavior.

Black hole observations with Advanced LIGO: status and future plans for the Advanced detector network

16 Sept
12:05
Invited

Sheila Rowan
Institute for Gravitational Research, University of Glasgow, UK

In February of this year the LIGO Scientific Collaboration and Virgo Collaboration announced the first detection of gravitational waves - with the waves being produced by the inspiral and merger of large stellar-mass black holes. This observation has opened up a new frontier and initiated the field of gravitational astronomy and astrophysics. This talk will review the status of observations, future planning for the global network of Advanced gravitational wave observatories, and some of the longer term intrumental developments under current study.

Posters

MOPTOP : a Multiwavelength OPTimized Optical Polarimeter for time domain astrophysics

Poster 30

Helen Jermak[1,2], Iain A. Steele[1] and Robert J. Smith[1]

[1]Liverpool John Moores University, UK; [2]Lancaster University, UK

We present the design and science case for a new polarimeter; MOPTOP: a Multicolour OPTimised Optical Polarimeter which is optimised for sensitivity and bi-colour observations. Its location on the worlds largest fully autonomous robotic telescope, the Liverpool Telescope (LT), will allow it to become the communitys most powerful instrument for probing transient astronomical sources such as powerful gamma-ray bursts, blazars and X-ray binaries. It will enable the first measurements of dust production rates and surface composition in a large sample of solar system objects currently being discovered by the ESA Gaia space mission.

Working on the scientific success of the predecessor polarimeter, RINGO3, we introduce an optimised polarimeter which is only limited by the photon counting efficiency of the detectors. Using a combination of six CMOS cameras, a half-wave plate and a wire grid polarizing beamsplitter, we can accurately measure multicolour polarisation of sources down to 4$\sim$19th magnitude with much lower systematics ($<$0.1%) and variability timescales as short as a few seconds. This will allow accurate measurements of the intra-nightly variability of the polarisation of sources such as gamma-ray bursts and blazars (AGN orientated with the jet pointing toward the observer), allowing the constraint of magnetic field models revealing more information about the formation, ejection and collimation of jets.

Although the MOPTOP design was produced for the specifications of the LT, we also intend the instrument design to be fully accessible to the public domain and we encourage copies to be placed on other smaller robotic facilities to allow better sampling of transient sources.

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