Monitoring the non-thermal Universe 2018

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Book of Abstracts

Contents

Theory / **1**

The First and Second-Order Fermi Acceleration Processes in BL Lacertae Objects

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BL Lacertae objects (BL Lacs) constitute a rare class of active galactic nuclei (AGNs) with the extreme observational features attributed to the Doppler-boosted emission from a relativistic jet, closely aligned to our line-of-sight. The spectral energy distribution (SED) of these sources, extending over 17-19 orders of the frequency from radio to the TeV energy range, is of non-thermal origin and shows a typical two-component structure. The lower-energy component, ranging from the radio-band to X-rays, is widely accepted to be a synchrotron radiation emitted by ultra-relativistic electrons/positrons/protons, to be initially accelerated via the Blandford-Znajek mechanism or magneto-hydrodynamic processes in the vicinity of the central super-massive black hole. However, the accelerated particles should loose the energy, sufficient for the emission of the KeV-GeV photons, very quickly and the source can maintain its flaring state on the daily-weekly timescales only if some additional acceleration mechanisms are continuously at work. According to the different studies and simulations, the particles can gain a tremendous energy due to the propagation of relativistic shocks through the jet: by means of first-order Fermi mechanism at the shock front, or they undergo an efficient stochastic (second-order Fermi) acceleration close to the shock front, in the turbulent jet medium. Our intensive X-ray spectral study of the TeV-detected, bright BL Lacs (Mrk 421, 1ES 1959+650, Mrk 501) often shows the signatures of the stochastic acceleration , while those related to the first-order Fermi process are found relatively rarely. The TeV-undetected HBLs mostly do not show the signatures of effective stochastic acceleration in their jets.

Theory / **2**

On the connection of radio and γ-ray emission of blazars

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Blazars are a sub-category of radio-loud Active Galactic Nuclei having their jet pointing towards us and are known for their emission covering practically all frequencies of the electromagnetic spectrum. These sources, in some cases, exhibit a correlation between gamma-ray and radio emission, especially during flaring episodes. In this work, we construct a one zone leptonic model in order to explain these correlations. Adopting the hypothesis that high energy photons are by relativistic electrons close to the central black hole, we study the evolution of this population of particles as they move down the jet and lose energy by radiation and adiabatic expansion. Utilizing a numerical code, we calculate the multi-wavelength emission of these particles as a function of the radial distance which can be translated into a time coordinate once the velocity of the emitting region is known. In this scenario, gamma-rays are produced early on, when the electrons are still very energetic, while radio emission at a later time when the electrons have cooled and the emission region becomes optically thin to synchrotron self-absorption due to expansion. We will discuss the parameters entering our calculations (like the magnetic field strength, the density of relativistic electrons, etc) in connection to the observational data.

Theory / **3**

Models of Blazar Variability

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This talks reviews general theoretical aspects of modeling the broadband spectral variability of blazars. Both time-dependent leptonic and lepto-hadronic models will be discussed. Recent applications to the modeling of coordinated and unccoordinated (orphan flares) multi-wavelength variability of several prominent Fermi-LAT blazars will be discussed.

Optical / 4

RoboPol: Polarimetric monitoring of blazars

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After 5 years of polarimetric monitoring of blazars, the RoboPol project has uncovered several key characteristics of polarimetric rotations in the optical for these most variable sources. The most important of these is that polarization properties of the synchrotron emission in the optical appear to be directly linked with gamma-ray activity. I will discuss the evidence for this connection, as well as the broader features of polarimetric behavior in blazars that are key in making progress with theoretical modeling of blazar emission.

Theory / 5

Characterizing leptonic long-term variability in blazars

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Most research in blazar variability focuses on individual flares to explain acceleration and radiation mechanisms and improve on current models. These short-time events (minutes, hours or days) might not be representative of the underlying mechanisms causing small-amplitude variability and/or continuous emission present most of the time. We therefore investigate long-term (month to years) variability of blazar emission in the framework of current leptonic blazar models. For this purpose, we introduce generated time-dependent parameter variations which are based on typical Power Spectral Densities (PSDs) associated with the variability of accreation flows. The PSDs from the resulting light curves are analyzed and compared to one another as well as the PSD of the variation PSD. Correlations between light curves are also investigated to aid identification of charactersitic variation patterns associated with leptonic models.

Methods / 6

Multi-wavelength studies of blazars

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To provide a detailed understanding of blazar and its environment, we study variability over diverse timescales using various statistical methods. As optical flux variations in blazars are often followed by spectral changes, thus we examine their colour –magnitude relationship on diverse timescales which helps us to understand the origin of variability. Presence or absence of correlation among multiple frequencies, variability timescales or a quasi-periodic oscillation can be used to constraint the size of the emitting region and also derive black hole mass. For this, we have developed a suite of time series analysis techniques namely, Structure Function, Discrete Correlation Function, Lomb-Scargle periodogram, Wavelet analysis and Power Spectral Density which we apply to analyze blazar light curves. Further, to study the core-jet morphology of blazars, we develop a piecewise Gaussian fit analysis technique. Using this, we are able to find spectral indices, time lags, core position offset, core radius, mean magnetic field strength, and other jet parameters. In essence, we explore complex phenomena governing blazars through the analysis of observational data and its applications using various theoretical models which further helps us to understand the physics of the inner regions of blazars.

MWL / 7

Blazar variability from radio to TeV photon energies on timescales ranging from decades to minutes

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Variability power spectral densities (PSDs) of blazar light curves, crudly represented as $P(f) = Af^{-\beta}$, where A is the normalization and β is the slope, indicate that the variability is generated due to the underlying {\it stochastic} processes (i.e., $\beta \simeq 1-3$, characteristic of flicker/red noise). We present the results of our power spectral analysis on blazar sources using the standard Fourier decomposition methods as well as modeling the light curve as continuous-time auto regressive moving average (CARMA) process. We use decade-long multiwavelength light curves at very high energy $\gamma-$rays from the H.E.S.S. and the VERITAS, high energy $\gamma-$rays from the {\it Fermi}-LAT, X-rays from the {\it Swift}-XRT and the {\it RXTE}-PCA, multi-band optical/infrared from several ground-based telescopes as well as the {\it Kepler} satellite, and GHz band radio frequencies from MRO, UMRAO, and OVRO monitoring programmes. The novelty of our approach is that, by combining long-term and densely sampled intra-night light curves in the optical regime, we were able to construct for the first time the optical power spectrum of the blazar for a time domain extending from decades years down to minutes. Our analysis reveals that: (1) nature of processes generating flux variability at synchrotron frequencies is different from those at IC frequencies (β ~2 and 1, respectively); this could imply, that IC variability variability, unlike the synchrotron (radio-to-optical) one, is generated by superposition of two stochastic processes with different relaxation timescales, (2) the main driver behind the optical variability is same on years, months, days, and hours timescales which argues against the scenario where different drivers behind the long-term flux changes and intra-night flux changes are considered, such as internal shocks due to the jet bulk velocity fluctuation (long-term flux changes) versus small-scale magnetic reconnection events taking place at the jet base (intra-night flux changes). Implications of these results are discussed in the context of blazar emission models.

Radio / 8

Constraining the limiting brightness temperature and Doppler factors for the largest sample of radio bright blazars

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Relativistic effects dominate the emission of blazar jets complicating our understanding of their intrinsic properties. Although many methods have been proposed to account for them, the variability Doppler factor method has been shown to describe the blazar populations best. We use a Bayesian hierarchical code called Magnetron to model the light curves of 973 sources observed by the Owens Valley Radio Observatory's 40-m telescope as a series of flares with an exponential rise and decay, and estimate their variability brightness temperature. Our analysis allows us to place the most stringent constraints on the equipartition brightness temperature i.e., the maximum achieved intrinsic brightness temperature in beamed sources which we found to be $\langle \mathrm{T_{eq}} \rangle = 2.78 \times 10^{11}\mathrm{K} \pm 26\%$. Using our findings we estimated the variability Doppler factor for the largest sample of blazars increasing the number of available estimates in the literature by almost an order of magnitude. Our results clearly show that γ-ray loud sources have faster and higher amplitude flares than γ-ray quiet sources. As a consequence they show higher variability brightness temperatures and thus are more relativistically beamed, with all of the above suggesting a strong connection between the radio flaring properties of the jet and γ-ray emission.

Theory / 9

Gamma-Ray Astrophysics in the Time Domain

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I will highlight recent observational results concerning the timing characteristics of AGN at gamma-ray energies with a focus on indications for log-normality and QPOs. The findings will be discussed in the context of theoretical approaches to understand the physical origin of variability in AGN.

Gamma-Ray / 10

Monitoring of PKS 2155-304 and PKS 1510-089 with H.E.S.S.

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Despite several years of observation, the nature of blazars' variability remains still enigmatic.
Thus, simultaneous multi-wavelength monitoring, including observations in the TeV regime is an important tool for understanding the nature of these objects.
In this talk I will present results of H.E.S.S. monitoring of two famous blazars: BL Lacertae type one PKS 2155-304 and flat spectrum radio quasar PKS 1510-089, performed in 2015 and 2016.
Very high energy observations are complemented with multi-wavelength data gathered with the following instruments: Fermi-LAT, Swift-XRT, Swift-UVOT, Steward Observatory and ATOM telescope.
This rich set of data revealed non-obvious patterns and relations observed for both blazars, which indicates that physical processes responsible for the broadband emission are hard to explain.

Theory / **11**

The long-lasting activity in the FSRQ CTA 102

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The flat spectrum radio quasar CTA 102 (z=1.032) has exhibited a tremendous phase of its existence. Since early 2016 the gamma-ray flux level has been significantly higher than in previous years. It was topped by a 4-month long giant outburst, where peak fluxes were more than 100 times higher than the quiescence level. Similar trends are observable in optical and X-ray energies. We have explained the giant outburst as the ablation of a gas cloud by the relativistic jet that injects additional matter into the jet and can self-consistently explain the long-term lightcurve. Here, we argue that the cloud responsible for the giant outburst is part of a larger system that collides with the jet and is responsible for the years-long activity in CTA 102.

Multi-Messenger / **12**

Multi-messenger astronomy in the era of the Zwicky Transient Facility

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With the start of a wide-field optical photometric survey at the Zwicky Transient Facility (ZTF), a unique opportunity has begun to scan the northern sky for transients such as Core-Collapse Supernovae, Active Galactic Nuclei and Tidal Disruption Events. The scientific potential is achieved by combining a 47 sq. deg. camera that can perform a 3PI survey each night to a depth of 20.5 mag with the availability of multiple filters. Hence, ZTF has ideal features for multi-messenger astronomy. In this talk I will introduce the ZTF program and its major science goals, as well as highlighting the multi-messenger potential with the example of an online neutrino correlation search with IceCube.

Radio / 13

Delving Deeper into Blazar Cores with 3mm GMVA Polarimetric Observations

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In order to investigate the high energy emission and jet formation in blazars, we study a sample of gamma-ray bright AGN in a combined 7mm / 3mm Vlbi monitoring program. Here we present total and linearly polarized GMVA images of a sample of blazars from the VLBA-BU-BLAZAR program, obtained from May 2016 to March 2017. The lower opacity at 3 mm and high angular resolution, of the order of 50 microarcseconds, allow us to measure the angular sizes of the most compact features, which can be compared with those observed at 7 mm with the VLBA for the determination of the jet's physical parameters.
Moreover, Faraday rotation and spectral index analysis between the two frequencies (3 and 7mm) provide us information about the three-dimensional structure of the magnetic field with unprecedented angular resolution.
Preliminary results on the FSRQ CTA 102 show evidences of large-scale helical magnetic field in the mm-core region.

Theory / 14

From Electrons to Janskys: Comparing Synthetic TEMZ Model Light Curves to High-Cadence Data from the POLAMI and F-GAMMA Monitoring Programs

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I will present a suite of synthetic full Stokes single dish light curves generated from the Turbulent Extreme Multi-Zone (TEMZ) model of blazar emission. These synthetic light curves are created via ray-tracing through the TEMZ jet model and include the effects of optical depth, relativistic aberration, Faraday rotation, Faraday conversion, slow-light interpolation, and beam convolution. We have embarked upon a systematic study of the TEMZ model parameters in order to explore what impact variations in: (i) the mean magnetic field strength, (ii) the ratio of the thermal to magnetic pressure, (iii) the minimum cutoff in the electron power-law energy distribution, and (iv) the pitch angle of the magnetic field within the jet plasma can have on the variability in the observed levels of linear and circular polarization emanating from the model. Comparison of these synthetic light curves to the POLAMI and F-GAMMA data sets highlight both the strengths and the weaknesses of the TEMZ model's ability to reproduce the observed variability in the linear and circular polarized emission emanating from these sources of jetted non-thermal emission.

Theory / 15

Interpretation of the coincident observation of a high energy neutrino and a bright flare of blazar TXS0506+056

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On September 22nd 2017, the IceCube Neutrino Observatory reported a muon track from a neutrino with a very good positional accuracy. The alert triggered a number of astronomical follow-up campaigns, and the Fermi gamma-ray telescope found as counterpart an object named TXS0506+056 in a very bright, flaring state; this observation may be the first direct evidence for an extragalactic source of very high-energy cosmic rays. While this and subsequent observations provide the observational picture across the electromagnetic spectrum, answering where in the spectrum signatures of cosmic rays arise and what the source properties must be, given the observational constraints, requires a self-consistent description of the processes at work. Here we perform a detailed time-dependent modeling of these relevant processes and present a self-consistent model for the source. We find a slow but over-proportional response of the neutrino flux during the flare compared to the production enhancement of energetic cosmic rays. We also demonstrate that energetic cosmic-ray ions, which produce the neutrinos, provide emission in the hard X-ray band and, to a lesser degree, in TeV gamma rays, whereas optical photons and GeV-scale gamma rays are predominantly radiated by electrons. Our results indicate that especially future X-ray and TeV-scale gamma-ray observations of nearby objects can be used to identify more such events.

Gamma-Ray / 16

Implications of the VHE gamma-ray outburst of PKS 1510-089 in May 2016

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PKS 1510-089 is one of only a handful of flat spectrum radio quasars detected in very high energy (VHE, E > 100 GeV) gamma rays. Since the first detection in 2009, the source has been monitored VHE. Here, we present one special event that is a direct result of the monitoring effort. In May 2016, a major VHE gamma-ray flare was observed from PKS 1510-089 by the H.E.S.S. and MAGIC

telescopes. Within ~5h of observations the VHE gamma-ray flux changed by an order of magnitude showing short-term variability features for the first time. Despite a soft intrinsic spectrum and strong absorption in the extragalactic background light, the high flux of the source allowed us to measure the gamma-ray spectrum up to the energy of 0.7 TeV. We report on the results of these observations as well as of the supporting observations performed in the optical and GeV range. We also discuss implications for the interpretation of the observed emission.

Optical / 17

Blazar Optical Sky Survey - BOSS project (2013-2018) and the quasi-periodic variability of BL Lac

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The prototype blazar BL Lac is monitored in the frame of the Blazar Optical Sky Survey (BOSS) Project at the University of Athens Observatory (UOAO), during the period of 2014-2018. BL Lac is continuously observed on a daily basis, in order to achieve dense temporal coverage in optical wavelengths, and study the short time-scale flux variability. Several long-runs have been conducted, where the target is monitored for several hours during the night, aiming towards the IDV detection and characterization. In this presentation, the preliminary results of the frequency analysis are given, summarizing the achievements after the 5-year long operation of the BOSS Project, while the advantage of small, robotic and remotely controlled telescopes is highlighted.

Gamma-Ray / 18

Monitoring the TeV sky with HAWC

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The High-Altitude Water Cherenkov (HAWC) observatory is a wide field-of-view instrument under operations since March 2015 and located in the state of Puebla, México. HAWC observes two thirds of the sky daily at energies between 0.1 and 100 TeV with a duty cycle greater than 95%. This capability allows us to monitor unbiasedly known sources as the Mrk 421 blazar, to search blindly for transient sources as GRBs and flares from balzars and to follow up on external alerts as gravitational waves from LIGO, neutrino from Ice Cube and GRBs from satellite detectors. In this talk, highlights from our on-going monitoring program will be presented.

Multi-Messenger / 19

Fermi Gamma-ray Burst Monitor Observations of Gravitational Wave Counterparts

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The Fermi Gamma-ray Burst Monitor (GBM) routinely observes the unocculted sky for transient astrophysical phenomena in gamma-rays. On August 17th, 2017 Fermi-GBM detected GRB 170817A, the first unambiguous electromagnetic counterpart to a gravitational wave event. Observationally, GRB 170817A was an ordinary short GRB. Together with the distance information from the gravitational wave measurements, however this GRB is subluminous by orders of magnitude. I will discuss the gamma-ray properties and the possible interpretations of this multi-messenger event. I will present the enhancements the GBM team is making to prepare for future gravitational wave observations focusing on the sub-threshold events, those that do not trigger GBM. Archival searches for events similar to GRB 170817A are also ongoing. I will present some preliminary results from these searches.

Multi-Messenger / 20

Very-high-energy gamma-ray follow-up of gravitational waves with HAWC

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On August 17th, 2017 the LIGO and Virgo detectors observed gravitational waves consistent with a binary neutron star (BNS) coalescence, with spatial and temporal coincidence with a gamma-ray burst (GRB) detected by the Fermi Gamma-ray Burst Monitor. Subsequent emission in the optical, ultraviolet, infrared, X-ray and radio bands was also observed. This was a milestone in multi-messenger astronomy, and provided strong evidence in favor of BNS mergers being progenitors of short gamma-ray bursts. The High-Altitude Water Cherenkov Observatory (HAWC) is a large field of view (~2sr) continuously operating observatory sensitive to very-high energy (VHE) gamma rays (~0.1-100TeV). These characteristics make it well suited for observing or constraining the VHE emission of this kind of rapid transients. Furthermore, the BNS horizon of LIGO-Virgo means that the attenuation on a possible VHE emission would be minimal, improving the sensitivity of HAWC significantly with respect to the average GRB. We report on our follow-up observations during the LIGO-Virgo runs O1 and O2, and describe plans and prospects for run O3.

Gamma-Ray / 21

FACT - Unbiased Long-Term Monitoring at TeV Energies

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Co-author: FACT Collaboration

The First G-APD Cherenkov Telescope (FACT) is an imaging air Cherenkov telescope observing in the very high energy gamma-ray regime since October 2011. Thanks to its silicon-based photosensors and robotic operation, it has a stable performance and a maximized duty cycle. Therefore, it is ideally suited for long-term monitoring. Focussing on regular observations of a small selection of bright TeV blazars results in an unbiased and dense light curves.

In over six years of monitoring, a total of more than 11000 hours of physics data have been collected. Thanks to this extensive monitoring program, a target-of-opportunity program with X-ray satellites such as INTEGRAL, Swift, XMM-Newton and ASTROSAT have been set up. Alerts based on an automatic quick-look analysis are sent to the astronomical and multi-messenger community triggering multi-wavelength observations.

The presentation will summarize the FACT monitoring program and discuss results from various multi-wavelength studies.

Methods / **22**

On-the-fly data reduction for the Cherenkov Telescope Array

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The Cherenkov Telescope Array (CTA) is the next-generation ground-based gamma-ray observatory, currently in the prototyping and testing phase. CTA will consist of two arrays of imaging atmospheric Cherenkov telescopes, one in the Northern and one in the Southern hemisphere, reaching a sensitivity roughly five to ten times higher than existing instruments and covering an energy range from 20 GeV to 300 TeV. These design features will allow CTA to probe transient and time-variable gamma-ray phenomena with unprecedented precision.

Owing to the large number of telescopes (more than 100) with roughly 2000 pixels per camera, array trigger rates of the order of 10 kHz and nanosecond sampling, CTA will produce tremendous data rates and volumes posing a significant challenge to the on-site and real-time analyses. A critical aspect of these analyses is the on-the-fly data reduction to allow for an efficient handling of the data stream without significant impact on sensitivity. While there are several approaches to data reduction, we focus on the identification of signal- and background-containing pixels in a particular event, both gamma- or hadron-induced, with the aim to suppress or even completely discard the information in background-only pixels. In this contribution we present different methods of doing so, including wavelet- and deep-learning based, and discuss their respective performances.

Gamma-Ray / **23**

FACT- Studying the X-ray/gamma-ray correlation using 5 years of data

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The First G-APD Cherenkov Telescope (FACT) has been monitoring blazars at TeV energies for more than six years. Because of the automatic operations and the usage of robust solid state photosensors (SiPM, aka G-APDs), it has been possible to collect a large and unbiased data sample of more than 11,000 hours. One of the closest and brightest blazars in the gamma-ray/X-ray sky, Mrk 421, is classified as high-synchrotron-peaked BL Lac type object. It has been extensively monitored by the Large Area Telescope on-board of the Fermi satellite, and the BAT and XRT instruments on-board of the Swift satellite. Using FACT data in the very high energy regime, we study the X-ray/gamma-ray correlation between these two bands. We found a strong correlation that favors a one-zone synchrotron self-Compton model. In this context, also the bright outburst in April 2013 is investigated.

Multi-Messenger / 24

AMON Multimessenger Alerts: Past and Future

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The Astrophysical Multimessenger Observatory Network (AMON) was founded to tie the world's high-energy and multimessenger observatories into a single network, with the purpose to discover multimessenger sources, to exploit these sources for purposes of astrophysics, fundamental physics, and cosmology, and to explore project datasets for evidence of multimessenger source populations. Successes of AMON to date include the GCN AMON_ICECUBE prompt alerts for likely-cosmic neutrinos, multiple follow-up campaigns for likely-cosmic neutrinos including the IceCube-170922A event, and several archival searches for transient and flaring gamma-ray + neutrino and neutrino + cosmic ray multimessenger sources. Given the new dawn of multimessenger astronomy recently realized with the GW 170817A / GRB 170817A and IceCube-170922A events, we are planning to commission multiple multimessenger alert streams, including gravitational wave + gamma-ray and high energy neutrino + gamma-ray coincidence alerts, over the course of the next year. I will describe some past AMON analyses and review our plans for high-energy and multimessenger AMON alerts during what promises to be a very exciting year for multimessenger astrophysics. AMON welcomes expressions of interest from prospective triggering facilities and follow-up partners.

Radio / 25

VLBI Jet Kinematics of the TeV Blazar Mrk 421

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In September 2012, the blazar Mrk421 showed a remarkable and distinct radio flare most prominent at cm wavelengths, following a similar flare at gamma-ray energies that occured about 40 days earlier. The radio flaring bahavior indicates the injection of fresh plasma into the jet, which may lead to the formation of a new jet component on parsec scales. This can be verified in analysis of the VLBI jet structure. Hence, data from the Boston University Blazar Monitoring Program are used to study the VLBI jet structure of Mrk 421 before, throughout, and after the period of the multiwavelength flaring event. We investigate 15 epochs from January 2012 through July 2013 observed with the Very Long Baseline Array (VLBA) at 7mm wavelength. We find no major change in the parsec-scale jet structure of Mrk421, indicating that any perturbation at the base of the jet associated with the flare did not travel to scales resolved by VLBI.

Theory / 26

Blazars-driven beam plasma instabilities in the IGM

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The TeV-bright blazars induce cosmological beam-plasma instabilities through the emission of gamma rays: The gamma rays annihilate on the infrared-ultraviolet extra-galactic background light (EBL)

producing electron/positron pair-beams which drive the growth of linearly unstable beam-plasma waves during their propagation through the ionized intergalactic medium (IGM). This results in depositing the pair-beams energy into the IGM in form of plasma waves and eventually into thermal energy. Another possible mechanism that could dominate the energy loss of these pair-beams is the inverse Compton cascades (ICC) with the Cosmic microwave background (CMB) photons. This lead to the production of photons with GeV energies.

During the linear regime of the blazar-driven beam-plasma instabilities, the energy loss due to these instabilities greatly exceed that via ICC. However, due to uncertainties in the non-linear evolution of the instabilities, the dominance of the ICC mechanism is still a possibility. Each of these two mechanisms have a different physical implication for the thermal history of the IGM, affecting our understanding of cosmological structure formation, interpretation of Ly-α forest, etc.

In this talk, I will highlight our ongoing effects to probe different signatures of these two possibilities.

Gamma-Ray / 27

FACT - Systematic Study of Blazar Flux States at TeV Energies

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Blazars are known to show variability on time scales from minutes to years. This complicates the measurement of their ground state. For this, long-term monitoring is important to increase the chance to study the source in an all-time low state.

The First G-APD Cherenkov Telescope (FACT) is monitoring bright TeV blazars since more than six years and has collected between 1500 and 3000 hours of physics data per source for Mrk 421, Mrk 501, 1ES 1959+650 and 1ES 2344+51.4.

Studying flux distributions of the FACT light curves, both on the complete sample and on shorter time scales, the ground state of the sources is confined and the evolution of the flux level with time is measured.

The results of the study are used to determine trigger levels for automatic alerts to the AMON network for the generation of real-time multi-messenger coincidence alerts.

While Mrk 421 was active in all observing seasons, Mrk 501 and 1ES 1959+650 had both very active and very quiet seasons. 1ES 1959+650 showed a bright flaring activity in 2016 and slightly enhanced flux in 2015, 2017 and 2018. Mrk 501 was very active from 2012 till 2014. Then its flux decreased reaching a low level in 2017 and 2018.

In the presentation, the evolution of the flux levels and upper limits on all-time low states of the sources will be discussed.

Theory / 28

Theoretical models to explain the TeV gamma-ray and X-ray correlations exhibited in Blazars.

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The broadband spectral energy distribution (SED) of blazars has two well-separated bumps, one of low energy, peaking at soft X-rays and the other of high energy, peaking at hundreds of GeVs. The SED in most of blazars is well understood through the standard one-zone Self-Synchroton Compton (SSC) emission. However, if that is the case, a strong correlation between X-ray and TeV-emission is expected. During the last decade, several correlations among X-ray and TeV bands have been searched but they have not undoubtedly confirmed. Some studies have suggested serious deviations from the expected leptonic correlation. In this work, we propose a theoretical model to study the correlation between the TeV gamma-ray and X-ray emission in different time scales and levels of activities of blazars. This leptonic model depends basically on the bulk Lorentz factor, the size of emitting region, the electron number density and the strength of the magnetic field. In the particular case, we apply this model to describe the TeV gamma-ray and X-ray correlation reported in Mrk421. We explore regions of the parameter space where the current model can describe a unique correlation for different time scales and levels of activities.

MWL / 29

The New Spectral and Temporal Variability Phase of OJ 287: A Multi-wavelength View

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The BL Lac object OJ 287 exhibits a regular ~12 years quasi-periodic outburst in optical band. The latest of this outburst occurred in December 2015 and since then till July 2017, it has exhibited intense multi-wavelength (MW) activity with many new features never seen before. The overall MW activity can be divided into two phases: November 2015 –May 2016, exhibiting strong variability from near-infrared (NIR) to Fermi-LAT γ-ray energies (0.1 –300 GeV) and September 2016 –July 2017, showing intense NIR to X-ray variability with highest ever reported X-ray state of the source and a concurrent detection at very high energies by VERITAS but no variability at LAT γ-ray energies. Most of the variations during both the phases are accompanied by a strong change in polarization degree and polarization angle of the source. In the first duration, the MW variations are simultaneous while the spectral energy distributions (SEDs) show new component in NIR-optical and a change in the shape of -ray spectra along with shift. The NIR-optical bump is consistent with the standard disk description while the γ-ray spectra can be explained by inverse Compton scattering of photons from the BLR region which has been detected during such close encounter times in OJ 287. Variations during the second phase are also simultaneous except for one duration where X-rays leads the optical-ultraviolet by ~5-6 days. This duration also suggests the presence of systematic variations, appearing first at higher energies and then at lower. On the other hand, the broadband SEDs during high states is a sum of the typical OJ 287 SED with modified -ray spectrum and an HBL SED and can be reproduced in a two zome model, one located at sub-parsec scales and other at parsec scales.

Gamma-Ray / 30

Fermi: Ten Years of Monitoring the Gamma-ray Universe

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Since 2008, the Large Area Telescope and the Gamma-ray Burst Monitor on the Fermi Gamma-ray Space Telescope have been monitoring the entire sky at energies from less than 10 keV to more than 1 TeV. Photon-level data and high-level data products are made publically available in near-real time, and efforts continue to improve the response time. This long-duration, all-sky monitoring has enabled a broad range of science, from atmospheric phenomena on Earth to signals from high-redshift sources. The Fermi instrument teams have worked closely with multiwavelength and multi-messenger observers and theorists to maximize the scientific return from the observatory, and they look forward to continued cooperative efforts as Fermi moves into its second decade of operation.

Theory / 31

The Feasibility of Magnetic Reconnection Powered Blazar Flares

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Flaring in blazar jets has been found to occur at TeV energies on rapid timescales as short as minutes, implying the emission originates from a very compact region within the jet. Whilst the physical origin powering such flares is yet to be established, recent particle-in-cell (PIC) simulations have indicated that magnetic reconnection can plausibly produce plasmoids small enough to potentially power such flares. PIC methods are numerically robust, but difficult to scale up to the sizes likely needed to accurately model the environment within an astrophysical relativistic jet. I present work so far on a macroscopic reconnection model in which a spherical plasmoid is grown by merging with other plasmoids, and particle acceleration is undertaken by numerically solving the diffusion-loss equation. Radiative losses from synchrotron and synchrotron self-Compton are explicitly computed, producing flare profiles, timescales and allowing the modelling of the Spectral Energy Distribution. Preliminary results indicate that it is difficult to grow a plasmoid which is able to match observed TeV flaring profiles without simultaneously producing huge X-ray and optical flares, which have not been observed.

Optical / 32

Extending ATOM's Monitoring Capabilities

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ATOM is an optical telescope located at the H.E.S.S. site in Namibia. It monitors optical flux of roughly 300 known gamma-ray emitters. In the beginning of 2018, a new instrument has been installed with the aim of enhancing the capabilities of ATOM –including measuring sub-second variability and polarisation. I will give a short overview of the new instrument's design and present first results.

Methods / 33

Variability of Blazar Light Curves

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Active Galactic Nuclei emit radiation over the whole electromagnetic spectrum up to TeV energies. Blazars are one subtype with their jets pointing towards the observer. One of their typical features is extreme variability on timescales from minutes to years.
The fractional variability is an often used parameter for investigating the degree of variability of a light curve. By using public data from instruments monitoring blazars in various energy ranges, the variability of the sources can be studied depending on energy and time. Different detection methods and sensitivities of the instruments result in different cadence and time binning of the data sets.The effect of these differences in the fractional variability needs to be studied and taken into account for the physics interpretation.
On the one hand, systematic effects of cadence and time binning are investigated. On the other hand, the fractional variability is studied depending on energy and time.
This presentation shows the results of FACT data combined with multi-wavelength data.

Radio / 34

Centimeter-Band Linear Polarization Variability as a Probe of Blazar Jet Physics

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Magnetic field strength and geometry are fundamental properties which control the formation and evolution of relativistic jets, and their observed emission via the field's impact on particle acceleration. At centimeter-band, where the emission is well-known to be produced by the synchrotron process, magnetic field properties can be constrained using a wealth of data from both single-dish linear polarization measurements exhibiting time-resolved outbursts in light curves, and VLBA imaging data revealing the spatial distribution of this emission. I describe the 3-frequency, source-integrated linear polarization monitoring observations from the University of Michigan program (UMRAO), extending over 40 years for some sources, and MOJAVE VLBA polarimetry imaging results at 15 GHz obtained since 2002. I present recent results on the spatial distribution of the polarization and illustrate how the combined UMRAO and MOJAVE position angle data have been used to probe magnetic field geometry. An emerging picture for the parsec-scale jet includes shocks, a turbulent underlying quiescent jet, and an ordered helical magnetic field component.

Methods / **35**

Bayesian Imaging for Multi-Messenger Data with Information Field Theory

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Working with multi-messenger data comes with a variety of challenges. Ideally, one would like to take the prior information into account that the scientific object looks similar in neighbouring frequency channels. Moreover, data from radio telescopes has different statistical properties compared to data generated by gamma-ray telescopes: the former can be assumed to have Gaussian noise and the latter has Poissonian statistics. Finally, radio telescopes measure the Fourier transform of the sky. In contrast, gamma-ray telescopes measure single photons. Theoretically, all those aspects could be taken into account when performing a joint data analysis of e.g. radio and gamma-ray data resulting in one single spectral cube accompanied by its uncertainty.

Information field theory (IFT) provides a framework in which the above challenges can be addressed. IFT algorithms are nowadays computationally reasonably cheap and allow for a full Bayesian analysis of e.g. multi-messenger data. The IFT group led by Torsten Enßlin at the Max-Planck Institute for Astrophysics (Garching) maintains an open-source software package called NIFTy (Numerical Information Field Theory) which enables users to implement Bayesian algorithms relatively easily and may be used for a variety of applications related to Monitoring the Nonthermal Universe.

In the talk, the most recent developments in the area of multi-frequency radio imaging will be presented. Additionally, a proof of concept (with mock data) of multi-messenger reconstructions (Gaussian and Poissonian data combined) will be shown for the first time.

Theory / **36**

Time-resolved SEDs of the variable blazar PKS 1510-089

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Recent detections of coincidences between high-energy neutrinos and blazars in flaring states or outbursts have revived interest in hadronic emission components of blazar SEDs. However, calorimetric arguments demonstrate that only the very brightest and most-frequent flaring sources have a realistic probability of being detected by current neutrino telescopes. Among the brightest blazar flares seen in the sky since the beginning of Fermi-LAT operations in 2008, a dominant fraction has been seen from the flat-spectrum radio quasar PKS 1510-089. Its location in the southern sky favors the detection of putative neutrinos associated with these high-amplitude flares. We analyse and model the time-variable SED of PKS 1510-089 based on Fermi-LAT and multiwavelength data in various states of activities and test for signs of hadronic emission processes.

Methods / **37**

Biases in Gamma-ray and MWL timing studies of AGN

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Most gamma-ray emitting AGN are variable and multiwavelength temporal studies provide insights into acceleration and radiation mechanisms, source size, radiative re-processing and source structure.
The gamma-ray band is very wide and is explored with very different techniques. In different energy bands very different biases affect temporal studies. The biases have significant implication for statistical analysis within the spectral range covered by a single facility, for comparisons between different gamma-ray facilities and for analyses of multiwavelength correlations between other High Energy bands.
The study characterizes the most significant biases and presents examples of potential errors in AGN studies that are specific to the gamma-ray domain and correlations to the X-ray band. Astrophysical implications cover a wide range from AGN structure, acceleration processes, and fundamental physics.

Multi-Messenger / 38

Deciphering the violent universe through gravitational waves

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Four hundred years ago Galileo revolutionised the way we see the universe through his telescope. Since then fascinating yet bizarre astrophysical phenomena reveal our capricious universe. Using electromagnetic observations we have been discovering exciting events at different wavelengths. Surprisingly, the universe is eager to send us information through different kinds of waves which probe the extreme realm of physics from the birth of a star to its death. Gravitational radiation as space time waves is a new key to see our universe, especially events that are opaque to electromagnetic radiation. From a theoretical solution of Einstein's equations, we learned the existence of gravitational waves and how they carry the information properties of their sources. In this talk I will give an overview of gravitational waves as a new tool in astronomy, from waveform modelling of binary evolution to merger, and finally the connection to multi messenger astronomy.

Gamma-Ray / 39

MeV Observations of Relativistic Jet Sources with CGRO/COMPTEL for nine Years

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The COMPTEL experiment aboard the Compton Gamma-Ray Observatory (CGRO) explored the MeV sky (0.75 - 30 MeV) for more than 9 years between April 1991 and June 2000, providing many discoveries. Now, more than 18 years after the deorbit of CGRO, the COMPTEL data are still the forefront of our knowledge on the non-thermal soft gamma-ray sky (1 - 30 MeV), because no successor is yet operating.

The COMPTEL source catalogue (Schönfelder et al. 2000) lists 32 steady sources, which raised to more than 40 sources up to now. About half of them are jet sources, mainly blazars (e.g. 3C 273, 3C 279) and some compact binaries (e.g. Cyg X-1, LS 5039). We will summarize the observational status on jet sources at soft MeV energies, with emphasis on compact binary systems. We shall also point out some recent developments in the still ongoing COMPTEL data analysis, like new imaging techniques as well as well as new background reduction techniques being currently pursued, and - finally - discuss their scientific perspectives.

MWL / 40

Radio and GeV-TeV gamma-ray emission connection in the different blazar sub-classes

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Multi-frequency monitorings are an essential tool for investigating the possible connection between the different emission bands, allowing us to discern among the various emission mechanisms producing the observed radiation. In the case of blazars, a strong and significant correlarion was found between radio emission and gamma-rays between 100 MeV and 100 GeV, by using both concurrent and non-concurrent observations. However, the possible connection between radio and very high energy (VHE, E>0.1 TeV) emission still remains elusive, owing to the lack of a homogeneous VHE sky coverage.
In this talk I will present some results about a recent work in which we aimed to quantify and assess the significance of a possible connection between the radio emission on parsec scale measured by the very long baseline interferometry and GeV-TeV gamma-ray emission in blazars, which is a central issue for understanding the blazar physics. We use two large and unbiased Fermi-LAT AGN samples extracted from the 1FHL and 2FHL catalogs, and for comparison, we perform the same analysis by using the 3FGL 0.1-300 GeV gamma-ray energy flux.

MWL / 41

Exploring the Dominant Gamma-Ray Emission Mechanism using Multiwavelength Variability Analysis. Case Study: 3C 279

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In this contribution, I will present the results of a recently published paper on the Flat Spectrum Radio Quasar 3C 279. We use light curves that cover a time-frame of six years, at different wavelengths: Gamma-rays, X-rays, UV 3000 Å continuum, optical V band, Near-Infrared (NIR) JHK bands, 1mm, as well as optical spectropolarimetry.

By applying cross-correlation analysis, We find that the UV continuum, optical, and NIR bands are correlated with delay zero. This correlation suggests that the emission regions are co-spatial.

We also find a correlation between the UV continuum and the 1mm emission, implying that the dominant emission mechanism is synchrotron, and therefore the same is true for the optical and NIR. This is supported by the high optical polarization degree observed.

Based on the variability of the gamma-ray light curve, we identified three different activity periods (A, B, and C), and we repeated the cross-correlations between the different light curves, on each different period.

The results for activity period A suggest that the gamma-ray emission is dominated by Synchrotron Self-Compton. The results for activity period C imply that External Inverse Compton is the dominant gamma-ray emission mechanism. Meanwhile, activity period B shows flares in all bands, with exception of the gamma-rays which appear to not have any significant activity on this period.

We propose that the lack of gamma-ray activity during period B is caused by an increase in the electron-positron pair production. In order to test this, we developed an analytical model to calculate the interaction cross-sections for both, inverse Compton scattering and electron-positron pair production. Our results state that an increase in Lorentz factor can cause the pair production cross-section to increase at higher rates than the inverse Compton. This makes our theory plausible.

MWL / 42

Unravelling the complex behaviour of our closest very-high-energy gamma-ray blazars, Mrk421 and Mrk501

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Co-authors: Amit Shukla ; Fabrizio Tavecchio ; Gareth Hughes ; Josefa Becerra [2]; Mislav Balokovic

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Because of their brightness and proximity (z=0.03), Mrk421 and Mrk501 are among the very-high-energy gamma-ray objects that can be studied with the greatest level of detail. This makes them excellent astrophysical high-energy physics laboratories to study the nature of blazars. Since 2009, there has been an unprecedentedly long and dense monitoring of the radio to very-high-energy gamma-ray emission from these two archetypical TeV blazars. In the conference I will report recent highlight results obtained from these multiwavelength campaigns. Despite some differences in the variability patterns of these two sources, there are also a number of similarities that support a broadband emission dominated by leptonic scenarios, as well as indications for in situ electron acceleration in multiple compact regions. I will discuss the complexity in the temporal evolution of their broadband emission and the presence of different flavors of flaring activity. I will also show detailed observational and theoretical results related to the 2-week long highest X-ray activity observed with Swift-XRT since its launch almost 14 years ago. These multi-instrument observations have yielded thought-provoking results, and demonstrate the importance of performing a continuous monitoring over multi-year timescales to fully characterise the dynamics of blazars.

Gamma-Ray / 43

Monitoring at TeV energies, M@TE

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Blazars are extremely variable objects emitting radiation across the electromagnetic spectrum and showing variability on time scales from minutes to years. Simultaneous multi-wavelength observations are crucial for understanding the emission mechanisms. From radio via optical, X-ray to gamma rays, a variety of instruments, as Fermi and OVRO, are already monitoring blazars. At TeV energies, long-term monitoring is currently carried out by HAWC and FACT. Towards 24/7 continuous observations, the goal is to have similar monitoring telescopes at locations around the globe. With the M@TE (Monitoring at TeV energies) project, we will install an Imaging Air Cherenkov Telescope equipped with an improved version of the FACT camera at the site of San Pedro M\'artir in Mexico. Extending the observation time to up to 12 hours per night by combining data from FACT and M@TE allows to study blazar variability on the typical flaring time scales of a few hours providing the possibility to constrain variability time scales of the emission. In this work, we will present the status of the project.

Methods / 44

Timing and Spectral Variability in Black Holes

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The light curves of black hole X-ray binaries show variability on timescales from milliseconds to months. The variability is from X-ray-bright matter in the inner region of curved spacetime surrounding the black hole. We use Fourier techniques to identify timing signals such as quasi-periodic oscillations (QPOs) and intrinsic broadband/band-limited noise. These signals are not just due to overall variations in brightness, but variations in and interactions between spectral components. This burgeoning field of X-ray spectral-timing has seen a surge in developments of analysis techniques that measure rapid time-dependent spectral changes. In this talk I will review timing and spectral-timing techniques as applied to stellar-mass black hole observations, physical insights gained from this analysis, current and upcoming spectral-timing observatories, and the multi-wavelength future of (spectral-)timing.

MWL / 45

X-ray/gamma-ray Correlation in Blazars

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Many multi-wavelength campaigns have been carried out in the last years to study the correlation between the very high energy (VHE) gamma-ray emission and the X-ray emission in blazars. A

linear (even quadratic) correlation has been predicted as consequence of leptonic mechanisms being responsible for the VHE gamma-ray emission. Although the activity in these two energy ranges seems to be correlated in most of the observations, is not possible to establish a conclusive result yet. In this talk we present a comprehensive review of the several attempts to better describe this correlation and how the available models proposed so far provide a good description of the observations reported by several instruments

Gamma-Ray / 46

Monitoring blazars with Fermi-LAT and prompt triggering on flares

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Blazars exhibit strong variability, and abrupt changes in their flux are observed at high energies down to hour-, or even minute-time scales. Regular monitoring and prompt identication of these variations is key to organise quick follow-up observations. Thanks to its allsky monitoring capabilities, the *Fermi*-LAT is a very powerful instrument to survey the high energy sky and reveal such bursts. In this contribution, an automatic pipeline - FLaapLUC (*Fermi*-LAT automatic aperture photometry Light C<->Urve) - aiming at quickly providing alerts on variable activity in blazars is described, and applications to trigger ToO campaigns with H.E.S.S. are described.

Gamma-Ray / 47

Complex spectro-temporal gamma-ray behaviour of Mrk 501

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The blazar Mrk 501 is a well-known BL-Lac type object, highly variable, on timescales down to a few minutes at TeV energies.
For the study of its gamma-ray emission, we can now fully exploit the complementarity of Fermi-LAT and ground based telescopes. In particular, at TeV energies, the First G-APD Cherenkov Telescope (FACT) performs unbiased monitoring of a small sample of blazars including Mrk 501, providing more than 2400 hours of data on it since 2012. In June 2014, FACT recorded an exceptional outburst during a period of enhanced activity of the source.
Following the alerts, H.E.S.S. also observed the exceptionally high state of Mrk 501 providing the highest sensitivity at minute-timescales.
Profiting from the availablity of temporal and spectral information, on a wide range of temporal and energetic scales, we compute the gamma-ray power spectral density and flux PDFs, characterizing the energy spectrum in different flux states of the source.
We also highlight the negative effects that a biased monitoring can have on the spectral and temporal studies of gamma-ray sources.

Gamma-Ray / 48

Implications of observed short-timescale gamma-ray variabilities on blazars jets

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The locations of emission of gamma-ray radiation in active galactic nuclei jet are highly debated and it range from light-hours to a few light-year in quasar jets. The situation is more complex in the case of flat spectrum radio quasars, where the gamma-rays photons above 10 GeV may interact with the UV radiation from broad line region and get absorbed. I will be talking about the recent detections of high energy photons during the minute-scale variability at gamma-ray energies from flat spectrum radio quasars. The minute-scale variability and detection of high energy photons from blazar jets challenges the standard shock-in-jet scenario where gamma-ray emission of blazars is commonly assumed to be associated with shocks traveling down the jet or with the jet formation region. The observed fast variability could either indicate the dissipation of magnetic islands or protons in a collimated beam from the base of the jet encountering the turbulent plasma at the end of the magnetic nozzle.

Methods / 49

AstroSat, an Indian step towards space-based astronomical missions

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The AstroSat, space-based Indian multi-wavelength observatory, provides an unique platform to enable the access of a very broad energy band (E~ 0.012 - 120.0 keV). It has also displayed the capability of observing hard X-ray polarization (e.g. 100-380 keV for Crab) for bright objects like bright GRBs, Crab, Cyg-1 etc. However, the timing capability of AstroSat has been displayed for a number of X-ray binaries (XRBs) using data from LAXPC instruments. The very sensitive UVIT instrument onboard AstroSat is providing spectacular data in poorly explored UV bands.

The simultaneous coverage of broad-band emission is very crucial for understanding the various emission mechanisms in a variety of objects, e.g., stellar mass X-ray binaries and AGNs. A number of blazars are extensively monitored over the course ~2.5 years of operation by internal and external proposers. In this meeting I shall be emphasizing the multi-wavelength capability of AstroSat and its impact on the understanding of the emission from blazars and XRBs.

Radio / 50

AGN monitoring with very-long-baseline interferometry

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Active galactic nuclei (AGN) present rapid variability across the electromagnetic spectrum. In most cases, this can be explained with relativistic boosting along the line of sight. A very valuable approach to probe the nature of these objects is to study their radio morphology at the highest resolution available at present, provided by very-long-baseline interferometry (VLBI). While high-energy photons can be explained via inverse Compton scattering of soft photons, radio photons are mostly produced by synchrotron emission from the relativistic outflows powered from the super massive black holes at the centre of AGN. These jets display high variability and traveling features reaching apparent superluminal motions. VLBI monitoring at different wavelengths and including polarisation reaches sub-parsec scales (beyond the milliarsecond) and provides essential, complementary information to the multi-messenger studies of these highly energetic objects. I will present an overview of recent and ongoing VLBI projects devoted to AGN monitoring.

Multi-Messenger / 51

Monitoring and Multi-Messenger Astronomy with IceCube

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IceCube is the current largest neutrino observatory with an instrumented detection volume of 1 km^3 in the ice-sheet below the antarctic South Pole station. With a 4π field of view and an uptime of >99% it is constantly monitoring the full sky to find astrophysical neutrinos. With the detection of an astrophysical neutrino flux in 2013, IceCube opened a new observation window to the non-thermal universe. On September 22, 2017 the IceCube online system sent out an alert reporting on a high-energy neutrino event which is spatially and timely correlated at the 3σ level with a high-energy gamma-ray flare of the blazar TXS 0506+056. Multi-wavelength follow-up observation by several observatories revealed a coincident flare in very-high-energy gamma-rays. In addition, IceCube found an independent 3.5 σ excess of a time-variable neutrino flux in the direction of TXS 0506+056 in 9.5 years of previous data. These finding mark the first evidence for a multi-messenger observation of an astrophysical source, including neutrino emission. In this talk I will present the latest astrophysical IceCube results, focusing on the multi-messenger program of IceCube.

Multi-Messenger / 52

Information on the conference dinner

MWL / 53

Gamma-ray emission in radio galaxies under the VLBI scope

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We report on the first systematic VLBI and gamma-ray monitoring study of a representative sample of radio galaxies with strong compact radio emission, with the aim of exploring the intrinsic relationship between high-energy emission and pc-scale jet properties in active galactic nuclei (AGN). While a number of studies have firmly established a close relationship between the gamma-ray and radio properties of AGN in general, the samples considered are dominated by blazars, i.e. AGN featuring well-aligned, Doppler-boosting-dominated jets. This poses a challenge in disentangling the orientation-dependent effects from the intrinsic emission produced in AGN jets. Radio galaxies, on the other hand, have misaligned jets whose emission is much less affected by Doppler boosting. We find that the high-energy emission in the compact jets of radio galaxies is not strongly driven by orientation-dependent Doppler boosting effects, much unlike the situation in their blazar counterparts. However, a significant correlation between gamma-ray flux and radio flux still holds, suggesting a direct physical link between the intrinsic emission properties of AGN jets in the two wavebands. We base our study on the decade(s)-long VLBI monitoring provided by the TANAMI and MOJAVE programs, in combination with gamma-ray data from Fermi-LAT, and also report on the interplay between pc-scale jet kinematics and gamma-ray emission in key individual sources.