ABSTRACTS

X- AND GAMMA-RAY EMISSIONS FROM NLSY1 GALAXIES

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The recent observations by Fermi large area telescope (Fermi-LAT) showed that in addition to the radio galaxies and blazars, Narrow-Line Seyfert 1 (NLSy1) galaxies are also potential sources of gamma-rays. NLSy1 are AGNs with optical spectral properties similar to those of Seyfert 1 galaxies, except for having narrow Balmer lines and strong optical lines. Also they exhibit strong X-ray variability, steep X-ray spectra and relatively high luminosity. Using the gamma-ray data from recent 8.8 years of Fermi LAT observations and available data from the observations by Swift, the multiwavelength emission properties of 1H 0323+342, SBS 0846+513, PMN J0948+0022, PKS 1502+036 and PKS 2004-447 are discussed.

INVESTIGATIONS OF THE PHYSICAL NATURE OF THE EMERGENCE AND SPREAD OF RELATIVISTIC ASTROPHYSICAL JETS

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A series of experiments was carried out at the TsNIIMash laser facility “Neodim”[1] with a radiation power of 10 TW and an intensity of $\approx 2\times 10^{18}$ W/cm^2 to simulate the formation and development of astrophysical relativistic jets. It was shown that proton beams are emitted symmetrically in the forward and backward directions to the normal of the target surface. The maximum energy of fast protons and electrons was 5 MeV and 7 MeV respectively. At energies in the 0.8-1.7 MeV range, the ring structures of proton beams are clearly distinguishable with an angular divergence in the range of 5-25°.

The numerical magnetohydrodynamic calculations have shown that such laboratory experiments can simulate the formation of astrophysical jets with an anomalously small divergence. Moreover, such a plasma stream can form a distinct circular structure. These structures also can be explained as Alfven vortex solitons formed under the conditions of a quasistationary superstrong (>100 MG) magnetic field spontaneously generated in laser plasma. It is shown that this model can be used as a model of astrophysical relativistic jets.

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ON THE INTERNAL STRUCTURE OF RELATIVISTIC JETS COLLIMATED BY AMBIENT GAS PRESSURE

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Recent progress in VLBI observations of relativistic jets outflowing from active galactic nuclei [1] gives us the direct information about jet width dependence $r_{jet}(l)$ on the distance l from the ”central engine”. Being the missing link in previous works, this relation opens the possibility to determine the internal structure of a jet. We have considered relativistic jet submerged into environing medium with finite gas pressure P_{ext}. Neither external magnetic field nor infinitely thin current sheet were assumed. This approach allows us to construct reasonable solution in which both magnetic field and flow velocity vanish at the jet boundary $r = r_{jet}$. The evident connection between external gas pressure and internal structure of relativistic jet is determined. Change of jet profile was also predicted as a consequence of transition from magnetically-dominated to partically-dominated flowing. The change must be because of asymptotical relation for gamma-factor in case of magnetically-dominated jet $\Gamma \propto r\Omega/c < \sigma$ cannot be satisfied for large transversal radius and leads to rebuilding of relativistic outflow character for quite small σ.

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ANNIHILATION LINE FROM THE GALACTIC BULGE DUE TO ACTION OF LOW-MASS FLARE STARS

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We consider the low-mass flare stars which form the bulk of the population in the galactic bulge as a source of the positrons needed to form the observed narrow annihilation line from the galactic bulge. Estimates based on the observed flares in low-mass stars, together with observations of the annihilation line in solar flares, show that the rate of production of positrons in flares in the stars in the bulge may be sufficient to explain the formation of the narrow stationary annihilation line observed from the region of the galactic bulge.

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NUMERICAL MODELING OF THE WINDS FROM RELATIVISTIC OBJECTS

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Three types of relativistic flows will be discussed in the report. First of them is outflow of collimated plasma (jets) from some of AGNs demonstrating low ratio of the bolometric luminosity of the accretion disc over the kinetic energy flux of the ejected plasma. Second one is the interaction of the relativistic wind from pulsar with the outflow from companion Be star. This discussion is directed on the analysis of the physics of the binary system PSR1259-63/SS2883. And finally we discuss the physics of the winds from fast rotating stars of Be type. All the discussion is based on the numerical simulations of these outflows.

GAMMA LOUD BINARIES

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Gamma loud binaries are nowadays a complex supercategory of galactic, variable, gamma-ray emitting binary systems that includes different types of objects. These systems may host two stars or a star and a compact object, and one can classify them within the low- and the high-mass class depending on the mass of at least one of the binary components. In this talk, I will briefly introduce the different types of source detected so far, and sketchily focus in the arguably most interesting cases, their phenomenology, and underlying physics.

MAGNETIC ENERGY DISSIPATION AND STABILITY OF GRB JETS

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Today we understand that the relativistic jets that power GRBs and likely other energetic stellar explosions are launched magnetically through the rotation of compact objects at the center of the collapsing stars. Such jets carry most of their energy in the form of electromagnetic Poynting flux. Once the jet breach the star it accelerates to high Lorentz factor and emits a large fraction of its energy in -rays, which are seen as a GRB. This requires an efficient dissipation mechanism to transform the clean EM energy at the jet base into photons and kinetic energy of the radiating particles, without destroying the jet. Understanding how Poynting dominated jets dissipate their energy is therefore crucial for modeling these extreme events. I will show how the interaction of a jet with the stellar material leads to efficient dissipation of the EM energy deep inside the star up to a state of equipartition with thermal energy. I will then show how this equilibrium state stabilizes the jet from being disrupted by magnetic instabilities, whereas allowing for global kink modes to grow on the jet perimeter causing it to wobble. These motions reduce the jet propagation velocity and in some cases can prevent it from exiting the star within its lifetime. I will discuss the implications of this on jet connection to low luminosity GRBs and highly luminous supernovae.

BLAZAR VARIABILITY FROM PLASMOIDS IN RELATIVISTIC RECONNECTION

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The discovery of short-timescale variability (~ minutes to hours) in blazar gamma-ray emission pose an exciting challenge for blazar emission models. An excellent candidate for describing such events is the relativistic magnetic reconnection model, in which energy is transferred to compact regions, denoted as plasmoids, characterized by high Doppler-boosting and fast motions within the blazar jet. Recent 2D particle-in-cell (PIC) simulations have been able to fully capture the evolution and dynamics of these plasmoids. High-energy particles, accelerated during the reconnection process, are ultimately captured by plasmoids and undergo fast-cooling. By coupling PIC results with our radiative transfer model, we may track the temporal evolution of both the electron and photon distributions within each plasmoid thereby permitting us to obtain cumulative light curves for a chain of many plasmoids. Here, I will present the resulting light curves, their power-spectral densities, and discuss their dependence upon various model parameters and plasmoid sizes while making a direct comparison to blazar observations.

AGN WINDS - PROSPECTS AND CHALLENGES OF THEORETICAL MODELS

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Outflows are found in about a half of type I AGNs. Their velocities imply launching radii spanning from several hundreds Schwarzschild radii to parsec scales. Mechanisms responsible for the acceleration lacks distinctive observational signature, and significant degeneracy exists in fitting theoretical models to observations. The usual suspects for driving mechanisms are radiation, thermal and magnetic driving. In my talk I review current problems in theoretical modeling of AGN outflows such as models of winds with large-scale magnetic fields, mechanisms for Ultra Fast Outflows, and the relevance of dusty winds to feedback and to the problem of AGN obscuration and unification. I will suggest my perspective on what current state of the art accretion disk simulations are telling us about wind launching mechanisms. Emerging theoretical models suggest that winds are inseparable from of accretion and further progress cannot be made without progress in understanding of realistic accretion disks.

HIGH-POWER LASER LABORATORY ASTROPHYSICS: JET FORMATION AND MASS ACCRETION IN YOUNG STARS

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Accretion dynamics in the forming of young stars is still widely investigated because of limitations in observations and modelling. In our present understanding, matter from the accretion disk (10^{11}-10^{13} cm^{-3} / 2000 K) is connected to the star by the extended magnetosphere (0.1 -1 kG) and falls down into the stellar surface at the free fall velocity (500 km.s-1). At the impact, a shock is forming, leading to observable X-ray and UV emissions, the amount of each channel being still incompatible with the present shock dynamic modelling at the impact region. Through scaled laboratory experiments of collimated plasma accretion onto a solid in the presence of a magnetic field, we open the first experimental window on this phenomenon by tracking, with spatial and temporal resolution, the dynamics of the system and simultaneously measuring multiband emissions. This is performed using a laser-created thermal plasma embedded in an external 20T pulsed magnetic field. It results from that magnetized plasma expansion a collimated jet having an aspect ratio >10, a temperature of tens of eV, an electron density of 1.5×10^{18} cm^{-3} and propagating at 750 $km.s^{-1}$. This jet, acting as the accretion column following the magnetic field lines then impacts a solid obstacle located on its path, mimicking the stellar surface. This setup differs by many ways from previous experiments using unmagnetized shock-tube configurations having unwanted edge-constraints. We observe in our experiment that matter, upon impact, is laterally ejected from the solid surface, then refocused by the magnetic field toward the incoming stream. Such ejected matter forms a plasma shell that envelops the shocked core, reducing escaped X-ray emission. Discussed in the light of 3D-MHD simulations in the laboratory conditions as well as 2D-MHD astrophysical-scaled simulations, these experimental results shed light on one possible structure reconciling current discrepancies between mass accretion rates derived from X-ray and optical observations.

ON THE ORIGIN OF HE AND VHE GAMMA-RAY FLARES FROM FSRQS

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The discovery of very high energy gamma-ray emission from Flat Spectrum Radio Quasars (FSRQs) by ground based Cherenkov telescopes (HESS, MAGIC, VERITAS) provides a new view of blazar-emission processes. The available data from multiwavelength observations of FSRQs, allow us to constrain the size (possibly also location) of the emitting region, magnetic field, electron energy distribution and etc., which are crucial for understanding the jet properties. We will investigate the origin of emission from FSRQs (3C 279, PKS 1510-089, PKS 1222+216 and PKS 1441+25), by modeling the broadband spectral energy distribution in quiescent and flaring states. By estimating the parameter space, that describes the underlying particle distribution responsible for the emission through the Markov Chain Monte Carlo technique, particle acceleration/emission processes will be investigated.

CALCULATION OF THERMAL CONDUCTIVITY COEFFICIENTS OF ELECTRONS IN MAGNETIZED DENSE MATTER

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The solution of Boltzmann equation for plasma in magnetic field, with arbitrarily degenerate electrons and non-degenerate nuclei, is obtained by Chapman-

Enskog method. Functions, generalizing Sonin polynomials are used for obtaining an approximate solution. Fully ionized plasma is considered. The tensor of the heat conductivity coefficients in non-quantized magnetic field is calculated. For non-degenerate and strongly degenerate plasma the asymptotic analytic formulas are obtained, which are compared with results of previous authors. The Lorentz approximation, with neglecting of electron-electron encounters, is asymptotically exact for strongly degenerate plasma.

We obtain, for the first time, in three polynomial approximation, with account of electron-electron collisions, analytical expressions for the heat conductivity tensor for non-degenerate electrons, in presence of a magnetic field. Account of the third polynomial improved substantially the precision of results. In two polynomial approximation our solution coincides with the published results.

For strongly degenerate electrons we obtain, for the first time, an asymptotically exact analytical solution for the heat conductivity tensor in presence of a magnetic field. This solution has considerably more complicated dependence on the magnetic field than those in previous publications, and gives several times smaller relative value of a thermal conductivity across the magnetic field at $\omega\tau >\approx 0.8$.

THE COCOON EMISSION - AN ELECTROMAGNETIC COUNTERPART TO GRAVITATIONAL WAVES FROM NEUTRON STAR MERGERS

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Short Gamma-Ray Bursts (SGRBs) are believed to arise from compact binary mergers (either neutron star-neutron star or black hole-neutron star). In this scenario their jets must penetrate outflows that are ejected during the merger. As a jet crosses the ejecta it dissipates its energy, producing a hot cocoon which surrounds it. I will present 3D numerical simulations of jet propagation in mergers' outflows and their resulting emission. This emission consists of two components: the cooling emission, the leakage of the thermal energy of the hot cocoon, and the cocoon macronova that arises from the radioactive decay of the cocoon's material. This emission gives a brief (~ one hour) blue, wide angle signal. While the parameters of the outflow and jet are uncertain, for the considered configurations the signal is bright (~ -14 – -15 absolute magnitude) and outshines all other predicted UV-optical signals. The signal is brighter when the jet breakout time is longer and its peak brightness does not depend strongly on the highly uncertain opacity. A rapid search for such a signal is a promising strategy to detect an electromagnetic merger counterpart. A detected candidate could be then followed by deep IR searches for the longer but weaker macronova arising from the rest of the ejecta.

THE PROPAGATION OF A CHOKED JET IN A POWER-LAW EXTERNAL DENSITY

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Long gamma-ray bursts are thought to arise from compact object-powered jets that drill through their host star, but if the jet duration is short or the progenitor is extended, the jet may be choked before reaching the stellar surface, dumping all of its energy into a hot cocoon. The observed breakout signature in this case will depend strongly on the geometry of the expanding cocoon at breakout. We present an analytical solution for the propagation of a choked jet outflow in a power-law density profile ($\rho \propto R^{-\alpha}$), derived using the Kompaneets approximation, i.e. by assuming that the cocoon pressure is uniform, the external shock is strong, and the outflow velocity is always normal to the cocoon surface. Additionally, we conduct numerical simulations of choked jets for $\alpha = 1$, 2, and 2.5, finding excellent agreement with the analytical prediction. The analytic model of [1], which

describes the jet and cocoon propagation up until the jet is choked, can be joined with our solution to obtain the complete evolution of the jet-cocoon system in a power-law medium, both while the jet remains active and long after it has shut off. Our results can be used to estimate the opening angle of a choked-jet outflow at breakout. However, we caution that our solution only applies as long as causal contact is maintained in the cocoon; if the flow encounters a steep density gradient near the stellar edge, this may not hold all the way up to breakout.

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SELF-CONSISTENT NEUTRAL CURRENT FILAMENTS IN A RELATIVISTIC COLLISIONLESS PLASMA

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An analytical description of a new broad class of the cylindrically symmetric magnetostatic structures (filaments) in a collisionless relativistic multicomponent plasma is given by means of the method of invariants of particle motion (PRL 104 (2010) 215002; Physics-Uspekhi 59 (2016) 1165). Namely, the Vlasov-Maxwell equations are reduced to a nonlinear damped oscillator equation, with an explicit form of an effective nonlinear potential, for the particle distribution functions (PDFs) with a polynomial-exponential dependence on a longitudinal momentum. The particle distributions may be essentially different from the Maxwellian ones and vary along the radial direction self-consistently with the profile of azimuthal magnetic field of the filament. We present a classification of possible radial profiles of a current density in these filaments, including zero, finite and infinite values of the total current as well as various spatial scales, both thin and thick with respect to a typical particle gyroradius.

We investigate in detail several simplest cases of the exponential, sum of two exponentials, quadratic, third- and fourth-order polynomial PDFs. In the first case we find a generalization of the Bennet pinch for arbitrary energy distribution of particles, which influences strongly the filament size as compared to the Maxwellian distribution for a given value of total current. In the third case we come to a current density profile with the radial oscillations described by the Bessel function with a spatial scale which also depends strongly on the energy distribution of particles. In more complicated other cases we obtain well localized filaments with zero or finite total current and show that there are possible solutions with one or more changes of current density direction and a few changes of sign of the azimuthal magnetic field.

Our analytical results may be applied to the interpretation of the numerical simulations of the collisionless shock waves and to the analysis of various long-lived magnetic structures in the astrophysical plasmas (jets, winds, accretion disks) and laboratory laser plasmas, including description of the individual filaments in a quasi-magnetostatic turbulence.

ASTROPHYSICAL-RELATED STUDIES IN LABORATORY WITH MAGNETIZED LASER PLASMA: MAGNETIZATION APPROACHES

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Modern laser facilities when used along with the auxiliary sources of magnetic fields allow nowadays to approach plasmas with parameters, scaled up to some extend to astrophysical magnetized plasmas. Within some schemes, external magnetization may be succesfully used [1] and the produced plasmas frequently considered during the interaction as a possible source of shock waves, accelerated particles, jets and other interesting phenomena. Other possibility is an intrinsic magnetization of plasmas, taking place during the preparation process [2, 3]. Special interaction conditions makes possible to control the parameters of such plasmas in a wide range, making it a unique and promizing object in astrophysical studies in a laser laboratory.

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RADIOASTRON: GOING DEEP INTO AGN JETS

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Studies of jets in active galactic nuclei (AGN) with the extreme angular resolution are performed at 18, 6, and 1.3 cm by the Space VLB interferometer *RadioAstron* [1] which includes the space radio telescope *Spektr-R* and many sensitive ground radio telescopes in Russia, Europe, Asia, USA, South Africa, Australia, Japan. It has detected more than 160 AGNs at projected spacings up to 350 000 km (27 Earth diameters). Formal resolution as high as 11 μ as has been achieved for quasars observed at 22 GHz. Bright jets were successfully imaged by *RadioAstron* (e.g., [1, 2, 3]). They show a clear evidence for a spiral magnetic field structure in the jet base, well resolved edge-brightened structure and indications of plasma instabilities growing in jets. AGN survey results indicate that many AGN cores are significantly brighter than what was known before (e.g., [3, 4]). At the same time, extreme brightness temperature values of 10^{15} –10^{16} K are not observed. Implications of the survey results for the physics of AGN jets will be discussed.

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LABORATORY SIMULATION OF ASTROPHYSICAL JETS WITHIN FACILITIES OF PLASMA FOCUS TYPE

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A laboratory simulation of astrophysical processes is one of the intensively developed areas of plasma physics. Significant progress in the simulation of astrophysical jets has been achieved by using high-power lasers and Z-pinches. A new series of experiments has been launched recently on the Plasma Focus type facility PF-3 in the NRC Kurchatov Institute. The main goal is to study the mechanisms of the jets stabilization, due of which they can propagate at distances much greater than their transverse dimensions. The experiments with stationary gas filling revealed regimes in which a narrowly collimated plasma jet was formed, the head of which was no wider than several centimeters at jet propagation distances of up to 100 cm. The PF-1000 (IFPiLM, Warsaw, Poland) and KPF-4 (SFTI, Sukhum, Abkhazia) experiments are aimed at creating profiled initial gas distributions to control the conditions of plasma jet propagation in the background plasma.

Estimations of the dimensionless parameters, i.e. the Mach, Reynolds and Péclet numbers which were achieved during the experiments, showed that the PF-facilities can be used for the YSO jets modelling. The future experiments, which can allow one to understand the nature of the stable plasma ejections observed in many astrophysical sources, are discussed.

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INTERPLAY BETWEEN FIELDS, PARTICLES, AND RADIATION IN COMPACT RELATIVISTIC JETS

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Not available.

VHE OBSERVATIONS OF BINARY SYSTEMS PERFORMED WITH THE MAGIC TELESCOPES

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The improvement on the Imaging Air Cherenkov Technique (IACT) led to the discovery of a new type of sources that can emit at very high energies (VHE, E>100 GeV): the gamma-ray binaries. Only five systems are part of this exclusive class and the efforts to enlarge this family still continue. This discovery also led to question if X-ray binaries can emit at VHE, even if they are quite luminous in the X-ray domain. We summarize the latest results from the observations performed with the MAGIC telescopes on different systems like the gamma-ray binary LS I +61° 303 and microquasars like SS433, V404 Cygni and Cygnus X-1, which are considered potential gamma-ray emitters. The binary system LS I +61° 303 has been observed by MAGIC over a period of 8 years in a long-term monitoring campaign. We show the newest results of our search for super-orbital variability [1] also in context of contemporaneous optical observations. Besides, we will present the results of MAGIC observations of the only super-critical accretion system known in our galaxy: SS 433 [2]. We will introduce the microquasar V404 Cyg, which has been observed with MAGIC after it went through a series of exceptional X-ray outbursts in June 2015. Finally, we will report on the VHE results achieved with MAGIC after 100 hours of observations on the microquasar Cygnus X-1, recently detected at high energies (HE, E>60 MeV).

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FROM SCATTER-FREE TO DIFFUSIVE PROPAGATION OF ENERGETIC PARTICLES WITH EXACT SOLUTION OF FOKKER-PLANCK EQUATION

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Propagation of energetic particles through magnetized turbulent media is reconsidered using the exact solution of Fokker-Planck equation. This solution reveals

that our understanding of cosmic ray (CR) transport is inaccurate when treated diffusively for weakly scattered energetic particles. The poor understanding of CR transport obscures their sources and acceleration mechanisms. After the Fermi, PAMELA, and AMS-02 have discovered the electron/positron and p/He spectral anomalies, it becomes crucial to improve transport models for improving our understanding of the anomalies. We discuss and simplify the exact solution of Fokker-Planck equation [1] which accurately describes a ballistic, diffusive and transdiffusive (intermediate between the first two) propagation regimes. It is found that the transdiffusive phase lasts for a (surprisingly) long time, about $5t_c$ (scattering time) while starting as early as at a $0.5t_c$. Since the scattering rate is energy dependent ($t_c = t_c(E)$), a large part of the energy spectrum is not propagated diffusively or ballistically. Its treatment should utilize the exact solution of Fokker-Planck equation. A significant parts of the spectra affected by the heliospheric modulation, for example, can not be interpreted diffusively. We present a new, simplified version of an exact Fokker-Planck propagator. It can easily be employed in place of the Gaussian propagator, currently used in major Solar modulation and other CR transport models. Flaws in using the telegraph equation to model the CR propagation are also briefly discussed.

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ANOMALIES IN GALACTIC COSMIC RAYS: TIME FOR EXOTIC SCENARIOS?

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Recent observations of galactic cosmic rays (CR) in the 1-500 GeV energy range have revealed striking deviations from what deemed “standard.” The anomalies cut across hadronic and leptonic CRs. I discuss findings that challenge physical mechanisms long held responsible for the CR production in galactic supernova remnants (SNR). I also consider some new physics of particle acceleration in SNR shocks that is not part of conventional models but may explain the anomalies. However, a possible 20-30% excess remains unaccounted for in the e^+/e^+ ratio over the range of a few 100 GeV. If not explained by future models, it suggests an additional source of positrons such as a dark matter decay/annihilation or pulsar contribution. Earlier efforts to explain both the e^+/e^- and p/He anomalies with the “standard” models by adjusting the SNR environmental parameters and multiple sources are critically assessed.

THE FIRST LOCALIZATION OF A FAST RADIO BURST AND RESULTING HIGH-ENERGY IMPLICATIONS

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Fast Radio Bursts (FRBs) are transient sources that emit a single radio pulse with a duration of only a few milliseconds. They were firstly discovered ten years ago, and nowadays we have detected tens of these events using single-dish radio observatories. However, their physical origin remains completely unknown. The observed dispersion measures in the bursts suggest cosmological distances, thus making these events unexpectedly bright. Multiple scenarios have been proposed during these years: from cataclysmic events, as compact binary mergers or gamma-ray bursts, to super-giant pulses or magnetars. Several of these scenarios predict a multiwavelength emission, potentially observable at optical, X-rays, and gamma-rays.

The detection of multiple bursts in FRB 121102 excluded all the cataclysmic scenarios, at least for this particular FRB. Early this year we reported the first unambiguous localization of a FRB, the repeating FRB 121102. This localization

showed that the bursts are associated to a compact and persistent radio source with a size $\approx< 0.7\mathrm{pc}$. This source is located within a star-forming region in a low-metallicity dwarf galaxy at a redshift $z{\sim}0.19$. This environment resembles the ones where superluminous supernovae or long-duration gamma-ray bursts are produced. The nature of this persistent source and the origin of the bursts remain unknown, although a neutron star/magnetar energizing a young superluminous supernova, or a system hosting a massive black hole, are the most plausible scenarios to date.

Simultaneous X-ray and radio observations provided constraints to its putative X-ray counterpart, and currently on-going optical and gamma-ray campaigns would provide new constraints on the emission at high energies.

RECOLLIMATION SHOCKS IN RELATIVISTIC JETS

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Recollimation shocks appear associated with relativistic flows propagating through pressure mismatched atmospheres. Astrophysical scenarios invoking the presence of such shocks include jets from AGNs and X-ray binaries, and GRBs. I shall start reviewing the theoretical background behind the structure of recollimation shocks in overpressured jets. Next, basing on numerical simulations, I will focus on the properties of recollimation shocks in relativistic magnetizedd steady jets depending on the magnetic field configuration (force-free, non force-free; pitch angle) and the dominant type of energy. Synthetic radio maps from the simulation of the synchrotron emission for a selection of models in the context of parsec-scale extragalactic jets will be also discussed.

NON-HOMOGENEITIES IN GAMMA-RAY BURSTS AFTERGLOW LIGHT CURVES

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We discuss the non-homogeneous behavior of GRB afterglow light curves in optical range. By the non-homogeneous behavior we mean flashes, slow deviations from power law, bumps and wiggles in the light curve. We use several well sampled light curves of GRB afterglows. In particular we describe phenomenology, compare optical light curves with X-ray ones obtained by XRT/Swift [1] and classify the non-homogeneities.

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PRECURSORS OF SHORT GAMMA-RAY BURSTS IN THE SPI-ACS/INTEGRAL EXPERIMENT

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We have analyzed the light curves of short gamma-ray bursts detected in the SPI-ACS/INTEGRAL experiment from December 2002 to May 2014 to search for precursors [1]. Both the light curves of individual bursts and the averaged light curve of brightest bursts have been analyzed. Only in one case we cannot exclude the precursor among of a few candidates. We show that the fraction of short GRBs with precursors is less than 0.4% of all short bursts registered with SPI-ACS in energy range above ~80 keV. Statistical analysis of the averaged light curve for the entire sample of SPI-ACS short bursts also revealed no regular precursor. Upper limits for the relative intensity of precursors have been estimated.

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ISENTROPIC “SHOCK WAVES” IN NUMERICAL SIMULATIONS OF ASTROPHYSICAL PROBLEMS

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Strong discontinuities in solutions of the gas dynamic equations under isentropic conditions, i.e., with continuity of entropy at the discontinuity, are examined. Solutions for a standard shock wave with continuity of energy at the discontinuity are compared with those for an isentropic «shock wave». It is shown that numerical simulation of astrophysical problems in which high-amplitude shock waves are encountered (supernova explosions, modelling of jets) with conservation of entropy, rather than of energy, leads to large errors in the shock calculations. The isentropic equations of gas dynamics can be used only when there are no strong discontinuities in the solution or when the intensity of the shocks is not high and they do not significantly affect the flow.

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PHYSICAL PARAMETERS OF RELATIVISTIC JETS DURING FLARES

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Relativistic jets from active galactic nuclei in many ways demonstrate the extreme properties. The recent measurements using radio interferometry with extreme long bases of the brightness temperature for BL Lac and 3C 273 suggest the strong departure of jet properties from the equipartition. Together with the synchrotron self-Compton model these measurements allow to estimate the magnetic field in the radio core [1, 2]. Under assumption of local jet uniformity the non equipartition magnetic field is of the order of 10^{-2} G. However, the relativistic jet is certainly not uniform. For the simplest case of jets with small viewing angles (blazars) we can introduce the model transversal structure and obtain the magnetic field amplitude. Using model parameters, we obtain the amplitude magnetic field of the order of G, dropping towards the jet boundary. For both uniform and non uniform models the implied magnetic flux is consistent with the limiting flux suggested by the magnetically arrested disk model. Using these estimates for the magnetic field and the core shift effect, we obtain the particle number density and, thus, the measure of departure from the equipartition. For the uniform model the ratio of Poynting flux to the particle energy flux is of the order of 10^{-5}.

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ON A SOLUTION OF THE QUASAR’S CATASTROPHE PROBLEM

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For the model with using high accuracy of calculation - 48 signs of all roots of the equations in respect of the electron’s velocities for inverse Compton effect is stated - the new values of the roots of the equations (in according with laws of conservation of energy and momentum) the electrons recoils remain relativistic. On anthers opinion this fact allows to eliminate inverse Compton catastrophe. The derived maximal opening angle (0.08 arcsec) of the formed particle gives interpretation of appearance of thin jets near quasar.

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GRB PHYSICS

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Not available.

AGILE RESULTS ON RELATIVISTIC OUTFLOWS ABOVE 100 MEV

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Gamma-ray emission from cosmic sources at energies above 100 MeV is intrinsically non-thermal, and the study of the wide variety of observed Galactic and Extragalactic γ-ray sources provides a unique opportunity to test theories of particle acceleration and radiation processes in extreme conditions, and it may help to shed light on the foundations of physics itself.

AGILE [1] is an Italian Space Agency (ASI) space mission devoted to γ-ray observations in the 30 MeV - 50 GeV energy range, with simultaneous X-ray imaging in the 18-60 keV band. Launched in April 2007, the AGILE satellite has just completed its tenth year of operations in orbit, and it is substantially contributing to improve our knowledge of the γ-ray sky. I will summarize some AGILE highlights, focusing in particular on:

• Cygnus binaries (Cyg X-1 and Cyg X-3)
• the CRAB Pulsar Wind Nebula flares (Bruno Rossi Prize 2012)
• some flaring Blazars (such as 3C454.3, 3C279)
• the short GRB 090510 as a template for Gravitational Waves (GW) counterpart hunt.

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FAST RADIO BURST: SUPERPULSARS, MAGNETARS, OR SOMETHING ELSE?

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We discuss several possibilities to explain fast radio bursts (FRBs) — millisecond extragalactic bursts of radio emission with detected fluence from 0.1 Jy up to >100 Jy. About 20 different hypothesis have been proposed to explain this phenomena. Conjunction of observational data suggests that sources of these events are neutron stars. After a brief review of observational results and variety of proposed explanations, we focus on the magnetar model ([1, 2]), and on some aspects of the model of superstrong pulses of young energetic radio pulsars ([3, 4]). We discuss statistics and energy budget of FRBs in these scenarios. We conclude that at the moment several explanaitions remains possible, and the population of FRBs can be a mixture of sources of different types. The repeating FRB can be either source different from the rest of population, or and examle of the same type of sources caught during a brief period of enhanced activity.

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SOME PROBLEMS IN SPECTRAL MODELLING OF PULSATIONAL PAIR INSTABILITY SN 2006GY

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The idea of getting a large radiative flux during the interaction of the gas ejected in subsequent outbursts was proposed by Grasberg and Nadezhin [1] as an explanation of SNe IIn. A physical mechanism (pulsational pair-instability or PPI) for multiple explosions was suggested by Heger and Woosley [2]. The PPI is good mechanism for massive stars with initial mass appreciably ~100M_{sun}. Woosley et al. [3] applied this model to explain the Type IIn superluminous SN 2006gy with an energetic explosion of about ~$3 \cdot 10^{51}$ ergs. Narrow lines in the spectra of extremely luminous supernova SN 2006gy of type IIn indicate that the matter of the first ejections had velocities an order of magnitude lower than those of the ordinary supernovae. These narrow absorption features in Hα profile had velocities of roughly 200 km s^{-1} [4]. But the maximum velocity of the hydrogen-rich material of the first outburst is about ~2000 km s^{-1} [3]. We have modeled the spectra of narrow feature of H profile with taking into account time-dependent effect in the kinetics with a help of new original LEVELS software package [5]. We have shown that the velocity of the absorption minimum corresponds to photosphere velocity at least the first 100 days after explosion and satisfies observations.

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SEARCH FOR SIGNATURE OF THE LIGO GRAVITATIONAL WAVE EVENTS IN THE SPI-ACS GAMMA-RAY DETECTOR OF THE INTEGRAL OBSERVATORY

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We are searching for possible periodic-like signal around a time of detection of the LIGO gravitational wave events using wavelet technique. At least in one case in SPI-ACS/INTEGAL data we found a packet of periodic pulses coinciding to the LIGO trigger. We discuss nature of the packet of periodic pulses and possible electromagnetic emission signatures of a compact binary merging.

POPULATION III MICROQUASARS

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We present the first results obtained in the elaboration of a complete model of a microquasar where the donor star is from Population III. These stars do not have stellar winds so we consider that the mass loss is due exclusively to matter overflowing the Roche's lobe towards the compact object, a maximally rotating black hole. The rate of accretion should be extremely super-Eddington, with an intense mass loss from the system in the form of winds and jets. We calculate the relativistic particle content of the jet and the corresponding spectral energy distribution (SED) considering a lepto-hadronic model. Prospects for the cosmological implications of these objects are briefly discussed.

A COMMON CENTRAL ENGINE FOR LONG GAMMA RAY BURSTS AND TYPE IB/C SUPERNOVAE?

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Long-duration, spectrally-soft Gamma-Ray Bursts (GRBs) are associated with Type Ic Core Collapse Supernovae (SNe), and thus arise from the death of massive stars [1, 2]. In the collapsar model, the jet launched by the central engine must bore its way out of the progenitor star before it can produce a GRB [3, 4]. Most of these jets do not break out, and are instead "choked" inside the star, as the central-engine activity time, t_e, is not long enough [5, 6].

Modelling the long-soft GRB duration distribution assuming a power-law distribution for their central-engine activity times, $\propto t_e^{-\alpha}$ for $t_e > t_b$, we find a steep distribution ($\alpha \sim 4$) and *a typical GRB jet breakout time of* $t_b \sim 60\mathrm{s}$ *in the star's frame* (for more details see [7]). *The latter suggests the presence of a low-density, extended envelope surrounding the progenitor star*, similar to that previously inferred by [6, 8] for low-luminosity GRBs.

Extrapolating the range of validity of this power law below what is directly observable, to $t_e < t_b$, by only a factor of ~4-5 produces enough events to account for all Type Ib/c SNe. Such extrapolation is necessary to avoid fine-tuning the distribution of central engine activity times with the breakout time, which are presumably unrelated. In [7], we speculate that *central engines launching relativistic jets may operate in all Type Ib/c SNe*. Recently, such a scenario has been independently proposed by [9]. In this case, the existence of a common central engine would imply that (i) the jet may significantly contribute to the energy of the SN; (ii) various observational signatures, like the asphericity of the explosion, could be directly related to jet's interaction with the star.

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ENHANCED GAMMA RADIATION TOWARD THE ROTATION AXIS FROM THE IMMEDIATE VICINITY OF EXTREMELY ROTATING BLACK HOLES

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We examine the acceleration of electrons and positrons by magnetic-field-aligned electric fields in the polar funnel of an accreting BH. In the quiescent state of black hole (BH) X-ray binaries, radiatively inefficient accretion flows (RIAFs) cannot supply enough MeV photons that are capable of materializing as pairs in the magnetosphere. This charge starvation leads to an occurrence of a strong electric field along the magnetic field line around the null-charge surface, on which the rotationally induced Goldreich-Julian charge density vanishes. Applying the pulsar outer-magnetospheric lepton accelerator model to BH magnetospheres, we show that the null-charge surface (hence the gap) arises in the immediate vicinity of the event horizon due to frame-dragging, and that the gap luminosity increases with decreasing plasma accretion rate. Moreover, we show that the gamma-ray flux is enhanced along the rotation axis by more than an order of magnitude if the BH spin increases from $a = 0.90M$ to $a = 0.9999M$. Consequently, if a ten-solar-mass, almost-maximally rotating BH is located within 3 kpc, when its accretion rate is between 0.005% and 0.01% of the Eddington rate, its high-energy flare becomes detectable with the Fermi/Large Area Telescope, provided that the flare lasts longer than 1.2 months and that we view the source nearly along the rotation axis. Also, its very-high-energy flux is marginally detectable with the Cherenkov Telescope Array, provided that the flare lasts longer than a night and that our viewing angle is about 45 degrees with respect to the rotation axis.

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HYDROMAGNETIC PROCESSES AROUND BLACK HOLES

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Black holes are responsible for a wide variety of astrophysical phenomena. They devour stars, eject relativistic jets, affect star formation and galaxy evolution, and enrich the Universe with heavy elements. I will discuss how global general relativistic magnetized fluid dynamics numerical simulations allow us to use this activity to quantitatively probe strong-field gravity and constrain black hole physics in various astrophysical contexts.

PULSAR MAGNETOSPHERES

Andrey Timokhin
NASA/GSFC, USA

Radio pulsars, which had been serendipitously discovered exactly 50 years ago, are most probably the most extreme objects in the Universe accessible to our study. Although we still do not have a reliable quantitative pulsar model, in the last two decades a remarkable progress has been achieved in understanding of physical processes responsible for pulsar phenomenon. In this talk I will give a (naturally somewhat biased) overview of the current state of the problem and highlight the most important advances in the field.

MHD SIMULATION OF LABORATORY JETS

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We performed a numerical MHD simulation of a laboratory experiment using powerful lasers to study the formation and evolution of jets.

The laboratory experiment is as follows. A powerful laser instantly heats the target in a vacuum chamber from which charged particles begin to run. On the opposite side of the camera a detector is installed, which fixes the flow of particles.

To describe these processes and simulate plasma flow, we chose a numerical method, boundary and initial conditions. We investigated the picture of the flow and compared it with experiment. We found the distribution of the density of matter at various distances from the target and at different time, and investigated the possible structures of matter on the surface of the detector.

COLLECTIVE EMISSION FROM STELLAR WIND BUBBLES INTERACTING WITH AN EXTRAGALACTIC JET

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The inner regions of galaxies are rich in gas and stars that can interact with the jet and produce high-energy non-thermal emission, as well as significantly mass-charge the jet. Previous works have studied different interactions, be it with dense molecular clouds or massive stars and red giants with strong stellar winds, as detailed simulations of a single object, or semi-analytical estimations of the collective emission and dynamical effects along all the jet.

In this work we focus on a population of stars with strong winds, which accumulate material around them outside the jet, when in pressure equilibrium with the environment, in the form of a bubble. When these bubbles reach the jet, a shock is produced in the external layer, that may cause part of the material to be peeled away and carried upstream at the contact discontinuity. Part of the remaining bubble may penetrate the jet, and eventually detach and be accelerated up to relativistic speeds, producing non-thermal emission at large scales.

QUASIRELATIVISTIC EQUATIONS FOR THE SOLAR CORONA PLASMA AND A VARIANT OF RATIONALE OF ITS HIGH TEMPERATURE

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The quasi-relativistic equations are derived from nonrelativistic equations [1] bringing amendments in them. They comprise the continuity equations, and the equations for impulses and energies both for protons and electrons. It is so because the hydrodynamic and electric forces acting on them are similar, so, their impulses are also similar. The rife proton velocity in solar corona is 500 km/s and the consistent electron velocity for such impulse is 0.953 c, hence, the electrons must be taken into account and they are relativistic. Expressions for the collisional terms are also adapted to relativistic velocities. The lower estimate of heat emitting to warm protons due to friction between electron and proton flows is

$$dQ \approx \frac{m_e n_e}{8\tau_e}(3+r)V_e V_p dt, \tau_e = \frac{(m_e c^2(1-r))^2}{4\pi r^2 e^4 n_p V_e \Lambda} \tag{1}$$

where m_e - electron mass, n_e, n_n - concentrations, $\tau_e \tau_e$ - free path time, V_e, V_p - velocities, $r = \sqrt{1 - V_e^2/c^2}$, Λ - Coulomb logarithm. Amount dQ is sufficient to heat plasma up. Concentration $n_e = 10^{10}$ and amount of scattering energy compensate large free path time.

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INFLUENCE OF A PLASMA ON THE BLACK HOLE SHADOW

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We consider an influence of plasma on the shadow of black hole. It is the first attempt to investigation of the shadow in matter based on analytical calculations. Our main result is an analytical formula for the angular size of the shadow of the spherically symmetric black hole surrounded by plasma. As plasma is a dispersive medium, the radius of the shadow depends on the photon frequency. The effect of the plasma presence is significant only in the radio regime. We find that for an observer far away from black hole, the non-homogeneous plasma has a decreasing effect on the size of the shadow. We also derive an analytical formula for the boundary curve of the shadow of Kerr black hole in presence of plasma. See details in [1] and [2]. For review of plasma effects in gravitational lensing see [3].

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NON-THERMAL EMISSION RESULTING FROM A SUPERNOVA EXPLOSION INSIDE AN EXTRAGALACTIC JET

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Core-collapse supernova (SN) are found in galaxies with ongoing star-formation. If a starburst galaxy hosts an active galactic nuclei (AGN) with a relativistic jet, then the SN phenomenon could take place inside the jet. The collision of the SN ejecta with the jet flow leads to the formation of a shock, where particles could be accelerated up to relativistic energies. In this work, we analyze the non-thermal radiation produced by electrons accelerated as a result of a SN explosion taking place inside an AGN jet. We first analyze the dynamical evolution of the SN within the jet. Depending on the interaction height and the jet power, the supernova can achieve a relativistic regime, resulting in emission significantly enhanced by Doppler boosting for blazar sources. The evolution of the SN Lorentz factor and radius regulates the intensity of the non-thermal emission expected from the interaction.

ASTROSAT/CZTI: SPECTRAL, TIMING AND POLARIZATION PROPERTIES OF GRB 160509A

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A bright GRB 160509A is observed in Fermi and AstroSat/CZTI. The Swift tiled observations monitor the X-ray afterglows and many observations in optical and radio wavelengths were also performed by ground based telescopes. The LAT emission is highly correlated to its counterpart emissions at immediate low energies. The single pulse as seen in the main burst at low energies splits into two separate pulses at high energies. The main episode of the burst is followed by a precursor. The precursor has thermal spectra which smoothly evolve during the main episode. The emission became quiescent for sometime and emerged again with a low energy complex structure. A high polarisation for this GRB is measured from the Compton double scattering events during the main burst. We analyze the data for this GRB for temporal, spectral and polarization properties. The top-hat like spectrum, the existence of a high energy emission that can extend from a few hundred MeVs to GeVs, a sub-dominant thermal component, the clues from afterglow emissions (a reverse shock) and the existence of high polarisation are incompatible with the existing mainstream models of the GRBs. The variability in polarization is checked by measurements in two bright pulses of the main burst.

MULTICOLOUR MODELLING OF SN 2013DX ASSOCIATED WITH GRB 130702A

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We present optical observations of SN 2013dx, related to the Fermi burst GRB 130702A occurred at a redshift $z = 0.145$. It is the second-best sampled GRB-SN after SN 1998bw: the observational light curves contain more than 280 data points in $uBgrRiz$ filters until 88 day after the burst, and the data were collected from our observational collaboration (Maidanak Observatory, Abastumani Observatory, Crimean Astrophysical Observatory, Mondy Observatory, National Observatory of Turkey, Observatorio del Roque de los Muchachos) and from the literature [1, 2, 3, 4]. We model numerically the multicolour light curves using the one-dimensional radiation hydrodynamical code stella, previously widely implemented for the modelling of typical non-GRB SNe [5, 6]. The best-fitted model has the following parameters: pre-supernova star mass $M = 25\mathrm{M}_\odot$, mass of a compact remnant $M_{CR} = 6\mathrm{M}_\odot$, total energy of the outburst $E_{oburst} = 3.5 \times 10^{52}$ erg, pre-supernova star radius $R = 100\mathrm{R}_\odot$, $M_{^{56}Ni} = 0.2\mathrm{M}_\odot$ which is totally mixed through the ejecta; $M_\mathrm{O} = 16.6\mathrm{M}_\odot$, $M_\mathrm{Si} = 1.2\mathrm{M}_\odot$, and $M_\mathrm{Fe} = 1.2\mathrm{M}_\odot$, and the radiative efficiency of the SN is 0.1 per cent. The results of this work are published in [7].

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CHANDRA OBSERVATIONS OF GAMMA-RAY EMITTING RADIO GALAXIES

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Important information on the evolution of the jet can be obtained by comparing the physical state of the plasma at its propagation through the broad-line region (where the jet is most likely formed) into the intergalactic medium, where it starts to significantly decelerate. This approach can be fruitfully applied to the sources showing a large-scale jet long enough to be resolved by Chandra. Accordingly, we selected these radio galaxies from Fermi Large Area Telescope (Fermi LAT) third source catalog which have knot or hot spot structure in their large scale jet. Namely we compare the constraints on the physical parameters in the innermost (≤pc) and outer (≥kpc) regions of the same jet by means of a detailed multiwavelength analysis and theoretical modeling of the broadband spectra of M87, 3C 111, 3C 120, 3C 275.1, 3C 303, NGC 6251, Pictor A.

PARTICLE ACCELERATION AT REVERSE AND FORWARD SHOCKS IN SNRS

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Cosmic ray acceleration by astrophysical shocks in supernova remnants is briefly reviewed. Results of numerical modeling taking into account magnetic field amplification by streaming instability and shock modification are presented. Nonthermal emission produced by accelerated particles in young and old supernova remnants is compared with available data of modern radio, X-ray and gamma-ray astronomy. It is also shown that high energy neutrinos produced in supernova remnants of IIn extragalactic supernova can explain the recent IceCube detection of astrophysical neutrinos.