Theoretical Astroparticle Physics

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3 Brief description

Astroparticle physics is a new field of research emerging at the intersection of particle physics, astrophysics and cosmology. Theoretical development in these fields is mainly triggered by the growing amount of experimental data of unprecedented accuracy, coming both from the ground based laboratories and from the dedicated space missions.

3.1 Relativistic kinetic theory and its applications

We pay particular attention to presenting our results in relativistic kinetic theory in a systematic and pedagogic manner. This approach resulted in a lecture course created by G.V. Vereshchagin for the students of the IRAP PhD Erasmus Mundus Joint Doctorate program. This lecture course was also delivered at the XV Brazilian School of Cosmology and Gravitation in Mangaratiba, Brazil in 2012.

Based on this lecture course an ambitious monograph, co-authored by G.V. Vereshchagin and A.G. Aksenov from ICAD, RAS, with the title "Relativistic Kinetic Theory With Applications in Astrophysics and Cosmology", has been published by Cambridge University Press in 2017. This book with about 400 pages summarizes results of 10 years of work by the authors on relativistic kinetic theory. It consists of three parts. Part I presents the basic ideas and concepts of this theory; equations and methods, including derivation of kinetic equations from the relativistic BBGKY hierarchy; and discussion of the relation between kinetic and hydrodynamic levels of description. Part II introduces elements of computational physics, with special emphasis on numerical integration of Boltzmann equations and related approaches, as well as multi-component hydrodynamics. Part III presents an overview of applications ranging from covariant theory of plasma response, thermalization of relativistic plasma, and comptonization in static and moving media to kinetics of self-gravitating systems, cosmological structure formation, and neutrino emission during the gravitational collapse.

This book is targeted at beginning graduate students and researchers specializing in the field of astrophysics and cosmology, as well as at theoretical physicists working on kinetic theory. It contains necessary ingredients in order to start independent research in this fast developing field. Advantages over existing literature include: readers can appreciate the simplicity and universality of underlying physical principles applied to seemingly distinct systems; the book describes theory, numerical methods and applications of relativistic kinetic theory in a single volume; it discusses progress made in astrophysics during the last decades and the role played by kinetic theory.

3.2 Electron-positron plasma

Electron-positron plasma is of interest in many fields of physics and astrophysics, e.g. in the early universe, active galactic nuclei, the center of our Galaxy, compact astrophysical objects such as hypothetical quark stars, neutron stars and gamma-ray bursts sources. It is also relevant for the physics of ultraintense lasers and thermonuclear reactions. We study physical properties of dense and hot electron-positron plasmas. In particular, we are interested in the issues of its creation and relaxation, its kinetic properties and hydrodynamic description, baryon loading and radiation from such plasmas.

Two different states exist for electron-positron plasma: optically thin and optically thick. Optically thin pair plasma may exist in active galactic nuclei and in X-ray binaries. The theory of relativistic optically thin nonmagnetic plasma and especially its equilibrium configurations was established in the 80s by Svensson, Lightman, Gould and others. It was shown that relaxation of the plasma to some equilibrium state is determined by a dominant reaction, e.g. Compton scattering or bremsstrahlung.

Developments in the theory of gamma ray bursts from one side, and observational data from the other side, unambiguously point out on existence of optically thick pair dominated non-steady phase in the beginning of formation of GRBs. The spectrum of radiation from optically thick plasma is usually assumed to be thermal.

3.2.1 Relativistic degeneracy in the pair plasma

It is well known that at relativistic temperatures plasma becomes degenerate. In order to study relativistic degeneracy we have introduced the Bose enhancement and Pauli blocking factors in the Boltzmann equation that allows us to follow the relaxation of the pair plasma to Planck spectrum of photons and Fermi-Dirac distribution of electrons and positrons. This improvement allows us to study higher energy densities with respect to those treated before. However, for such high energy densities the assumption adopted in these works, namely that three-particle interactions operate on longer timescale with respect to two-particle ones, does not hold any longer. For this reason we had to introduce the collisional integrals for three-particle interactions based on the exact QED matrix elements, in full analogy with previously treated two-particle interactions.

In this work we consider relaxation of nonequilibrium optically thick pair plasma to complete thermal equilibrium by integrating numerically relativistic Boltzmann equations with collisional integrals computed from the first principles, namely from the QED matrix elements both for two-particle and three-particle interactions.

We point out that unlike classical Boltzmann equation for binary interactions such as scattering, more general interactions are typically described by four collisional integrals for each particle that appears both among incoming and outgoing particles.

Our numerical results indicate that the rates of three-particle interactions become comparable to those of two-particle ones for temperatures exceeding the electron rest-mass energy. Thus three particle interactions such as relativistic bremsstrahlung, double Compton scattering and radiative pair creation become essential not only for establishment of thermal equilibrium, but also for correct evaluation of interaction rates, energy losses etc. We found strong anisotropies in reaction rates in three-particle interactions.

This year we focused on reaction rates in degenerate relativistic plasma. We developed a new efficient method to compute Uehling-Uhlenbeck collision integral for all two-particle interactions in relativistic plasma with drastic improvement in computation time with respect to existing methods. Plasma is assumed isotropic in momentum space. The set of reactions consists of: Moeller and Bhabha scattering, Compton scattering, two-photon pair annihilation, and two-photon pair production, which are described by QED matrix elements. In our method exact energy and particle number conservation laws are satisfied. Reaction rates are compared, where possible, with the corresponding analytical expressions and convergence of numerical rates is demonstrated. For example, annihilation photon spectrum for reaction $e^+ + e^- \rightarrow \gamma + \gamma'$ is illustrated in Fig.3.1. Figure 3.1 shows that the method

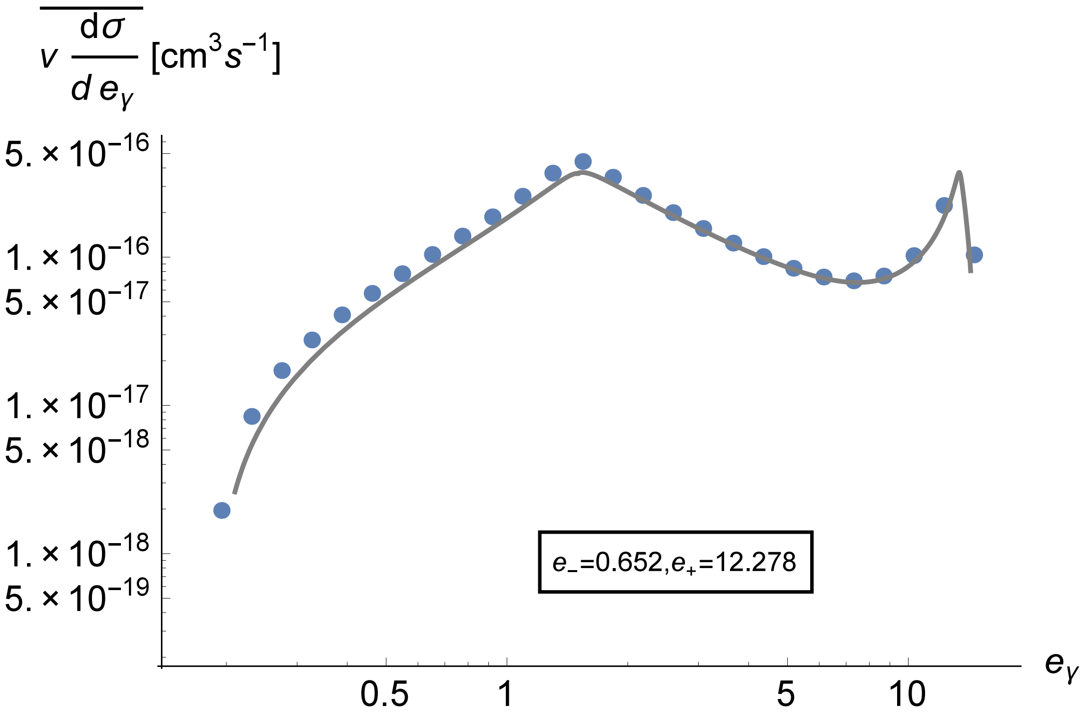

Figure 3.1: Distribution for pair annihilation $\overline{v\frac{d\sigma}{de_\gamma}}(e_\gamma, e_+, e_-)$. Analytic results are reproduced by the solid curve. Dots indicate numerical results.

is able to accurately reproduce all features in the spectrum of annihilation photons in the range of more than two orders of magnitude.

The paper describing these results is submitted for publication in the Journal of Computational Physics.

3.3 Thermal emission from relativistic plasma and GRBs

Emission from optically thick stationary plasma is an important topic in astrophysics. Such plasma confined by the gravitational field constitutes stars, accretion disks and other objects. The light from these systems is coming from the so called photosphere defined as a region where the optical depth computed from the interior of the optically thick plasma outwards reaches unity.

There are also dynamical sources where bulk velocities of plasma reach ultrarelativistic values such as microquasars, active galactic nuclei and gamma-ray bursts (GRBs). While in the former two objects there is clear evidence for jets which contain optically thin plasma, in the latter objects the issue of jets is controversial, and the source is required to be optically thick. This observational fact poses a new problem: the emission from (spherically) expanding plasma which initially is optically thick. Such plasma eventually becomes optically thin during its expansion, and initially trapped photons should be released.

Recently, thermal components were found in spectra of GRBs not only in the prompt emission, but also in the early afterglow. This motivated us to extend the study of thermal emission previously focused on ultrarelativistic photosphere into a more broad context of thermal emission from relativistic plasma in GRBs.

The interaction between the GRB ejecta and a baryonic shell is considered in the context of the binary driven hypernova model of GRBs. The kinematic and observational properties of the shell after the interaction are derived. In particular, the temperature and the duration of the thermal emission are obtained. The model is then applied to GRB 090618 and other sources, and the observed characteristics of the thermal component are reproduced. These results are published in the journal Astronomy and Astrophysics.

3.4 Ultra high energy particles

Last year we started a new research field on propagation of ultra high energy particles on cosmological distances. We consider cosmic limits on the propagation distance, or *cosmic horizon* due to interactions of such particles with known cosmological backgrounds, such as cosmic microwave background of photons, extragalactic background light, and cosmic neutrino background. We examine the mean free path and mean energy losss distances due to various interactions such as Breit-Wheeler process, photon-photon scattering, photopion process, Bethe-Heitler process, neutrino-neutrino scattering etc.

3.4.1 Photon-photon scattering and absorption of high energy photons in the Universe

We consider cosmic limits on propagation of very high energy photons set by their interactions with cosmic microwave background. It is well known, that the main process for a high energy photon interacting with the microwave background is the electron-positron pair production. It is less known, that photon-photon scattering is also important at high redshifts. The importance of this second process was first discussed by Zdziarski and Svensson in 1990. We calculate the optical depth due to two interactions: the Breit-Wheeler pair creation and the Euler-Heisenberg photon-photon scattering. Recently we developed a new method to take into account cosmic evolution of the background photons, as well as particle energy redshift. Using this method we have found that below the critical energy $E_{cr} \simeq 1.68$ GeV, and above the critical redshift $z_{cr} \simeq 180$ the photon-photon scattering indeed dominates over the electron-positron pair creation, see Fig. 3.2. The results of this work were presented at the meeting "Supernovae, Hypernovae and Binary Driven Hypernovae, An Adriatic Workshop" held on June 20-30, 2016 in Pescara, Italy. The results of this work are submitted to Astrophys. Space Sci. (2017). These results were also reported at the First ICRANet-Minsk workshop on high energy astrophysics, National Academy of Sciences of Belarus, Minsk, Belarus, April 26-28, 2017 and at the XIII International Conference on Gravitation, Astrophysics and Cosmology and 15th Italian-Korean Symposium on Relativistic Astrophysics: A joint meeting, Ewha Womans University, Seoul, Korea, July 3 - 7, 2017. The paper is accepted for publication in Astrophysics and Space Science.

3.5 Self-gravitating systems of Dark Matter particles

3.5.1 Fermionic dark matter in Galaxies

The problem of the distribution of stars in globular clusters, and more general in galactic systems, has implied one of the results of most profound interest in classical astronomy. Since the pioneering works of Michie Michie (1963) and King King (1966), they considered the effects of collisional relaxation and tidal cutoff by studying solutions of the Fokker-Planck equation.

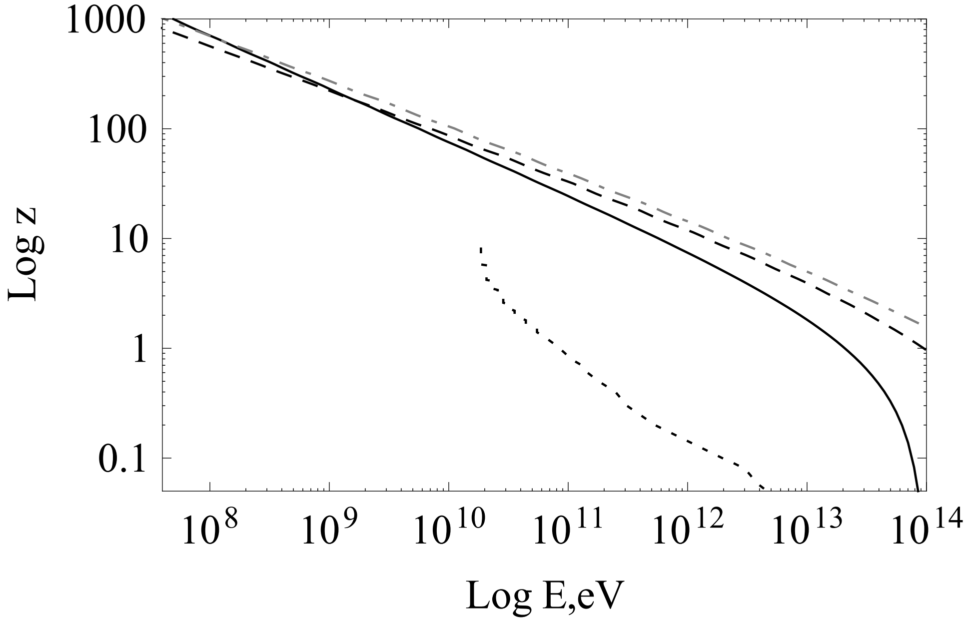

Figure 3.2: Cosmic horizon (defined from the condition $\tau = 1$) for photon-photon scattering (dashed curve) and for pair production from two photons (solid curve) as function of energy $E = h\nu_1$ of the high energy photon measured today on Earth. The dotted curve is the cosmic horizon due to the extragalactic background light, taken from Inoue (2013). For comparison also the condition $\tau = 5$ for photon-photon scattering is shown by dash-dotted curve.

There, it was shown that stationary solutions of this kind can be well described by lowered isothermal spheres models, based on simple Maxwellian energy distributions with a constant subtracting term interpreted as an energy cutoff. An extension of this statistical analysis with thermodynamic considerations, which includes the effects of violent (collisionless) relaxation, has been studied in Lynden-Bell (1967), with important implications to the problem of virialization in galaxies which are still of actual interest. In a series of works, Ruffini and Stella (1983); Gao et al. (1990); Ingrosso et al. (1992) changed the emphasis from self-gravitating systems of classic stars (which verify Maxwellian distributions) to systems of fermionic particles, with the aim of describing galactic DM halos. It was there considered a quantum fermionic distribution taking into account the possible presence of a cutoff in the energy as well as in the angular momentum. A remarkable contribution in the understanding of these issues was given in Chavanis (2004), based on the study of generalized kinetic theories accounting for collisionless relaxation processes, and leading to a class of generalized Fokker-Planck equation for fermions. It was there explicitly shown the possibility to obtain, out of general thermodynamic principles, a generalized Fermi-Dirac distribution function including an energy cutoff, extending the former results by Michie and King to quantum particles. More recently, it was shown that quantum particles fulfilling fermionic quantum statistics and gravitational interactions are able to successfully describe the distribution of galactic DM halos when contrasted with observations.

This was done through the development of a new model for the distribution of DM in galaxies, the Ruffini-Argüelles-Rueda (RAR) model Ruffini et al. (2015); Argüelles et al. (2016b), based on a self-gravitating system of massive fermions at finite temperatures. The RAR model, for fermion masses above keV, successfully describes the DM halos in galaxies (from dwarfs to spiral and ellipticals), and predicts the existence of a denser quantum core towards the centre of each configuration which could work as an alternative to the massive Black Holes. The main results regarding the astrophysical implications and predictions of the RAR theory are:

1. That a regular and continuous distribution of keV fermions can be an alternative to the black hole scenario in SgrA*, being at the same time in agreement with the Milky Way DM halo, and without spoiling the known baryonic (bulge and disk) components which dominate at intermediate scales Argüelles et al. (2016b) (See Fig. 3.3 for details).

2. By constraining the DM quantum core to have the minimum compactness required by the S2 star dynamics and by requesting the gravitational stability of the entire DM configuration, the fermion mass can be constrained to the range $48\,\mathrm{keV} \lesssim mc^2 \lesssim 345\,\mathrm{keV}$ Argüelles et al. (2016b) (See Fig. 3.3 for details).

3. By extending this novel approach to different galaxy types with given halo observables (see Fig. 3.4 for the full family of possible RAR solutions in each galaxy-case), and for fermion masses in the keV range, the model is shown to be consistent with (a) the observationally inferred correlations between the mass of the dark central object and total DM

halo mass Ferrarese (2002); Kormendy and Bender (2011); Bogdán and Goulding (2015), and with (b) the observationally inferred (universal) value of the inner surface density of DM halos Donato et al. (2009), from dwarf to elliptical galaxies Argüelles et al. (2016b). See Fig. 3.5 and Fig. 3.6 for more details regarding (a) and (b) respectively.

On the other side, the possibility that the dark matter particles interact among themselves via some other (i.e. besides gravity) fundamental interaction, is an open issue within the DM community which has gained increasing attention in the last two decades. Thus, self-interacting dark matter (SIDM) is a hypothetical form of dark matter (DM), characterised by relatively strong (compared to the weak interaction strength) self-interactions, which has been proposed to resolve a number of issues concerning tensions between simulations and observations at the galactic or smaller scales.

Originally, the self-interactions of the DM particles are modeled by classical mechanics descriptions Spergel and Steinhardt (2000); Davé et al. (2001), without making any reference to the details of the interactions. Instead, we have recently in Argüelles et al. (2016a), studied the possible consequences caused by a *self-interacting relativistic field theoretical model* of Majorana fermions were analyzed, with vector type interactions and fermion rest-masses in the keV/c^2 range, playing the rôle of DM in galaxies. In particular, the collisionless nature of the DM fermions at halo scales were maintained, while studying the two-particle self-interaction effects for different interaction strengths, but only in the (sub-pc) region, where the dense fermionic quantum core proper of the RAR model arises Ruffini et al. (2015); Argüelles et al. (2016b). Such an extension of the original RAR model by including (beyond standard model) self-interactions among the particles was then analyzed in Argüelles et al. (2016a), making emphasys in its application to galaxies such as large elliptical harboring massive central dark objects of $\sim 10^9 M_\odot$. Importantly, for the first time, it was there calculated the total cross-section σ among the inos from an electroweak-like formalism, and compared with other observationally inferred cross-section estimates such as the ones recently studied in Rocha et al. (2013). Finally, comparison among different interesting particle-physics inspired SIDM models, such as the glueball DM, and a right-handed neutrino DM (with mass of a few tens of keV, that may exist in minimal extensions of the Standard Model) were reported in Mavromatos et al. (2017). Paying particular attention to

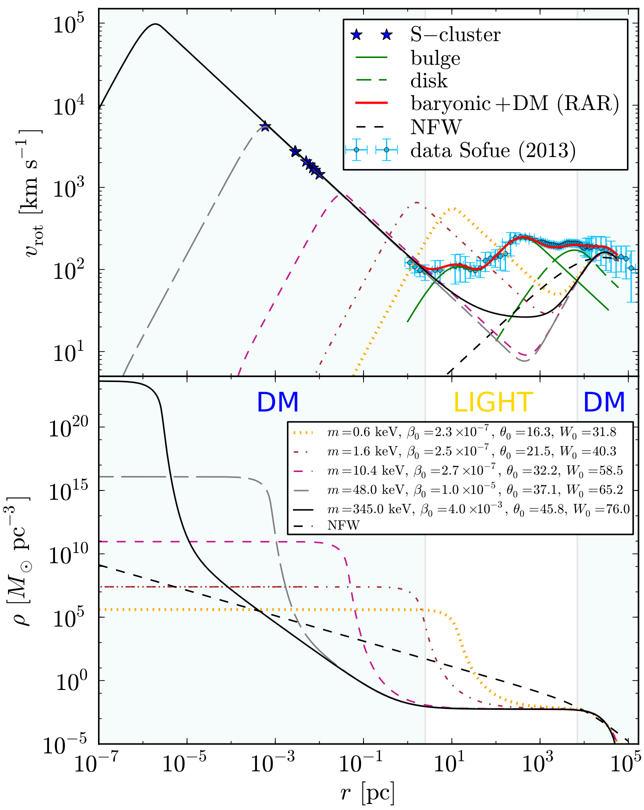

Figure 3.3: Theoretical rotation curves (upper panel) and density profiles (lower panel) for different DM fermion masses in the keV region, in agreement with all the Milky Way observables from $\sim 10^{-3}$ pc to $\sim 10^{5}$ pc. The continuous thick-red curve that fit the observed data (blue points) is the total rotation curve given by the RAR model plus the baryonic (bulge + disk) component without the need for a central BH, i.e. using any RAR profile for $mc^2 = 48$–345 keV. We also show, for the sake of comparison, the contribution of the NFW DM profile to the total rotation curve (not shown here) which produces an equally good fit to the data in the halo region Sofue (2013). The lower bound of the ino mass, $mc^2 = 48$ keV, comes from the minimum compactness required by the S2 star dynamics, while the upper bound $mc^2 = 345$ keV, is set by the gravitational stability of the entire DM configuration. The stars-symbols represent the eight best resolved S-cluster stars Gillessen et al. (2009), whose positions in the plot indicates the *effective* circular velocity at pericentre (i.e. without considering the ellipticity of the orbits). The DM contribution to the Galactic halo becomes necessary above ~ 7 kpc, in agreement with Iocco et al. (2015)

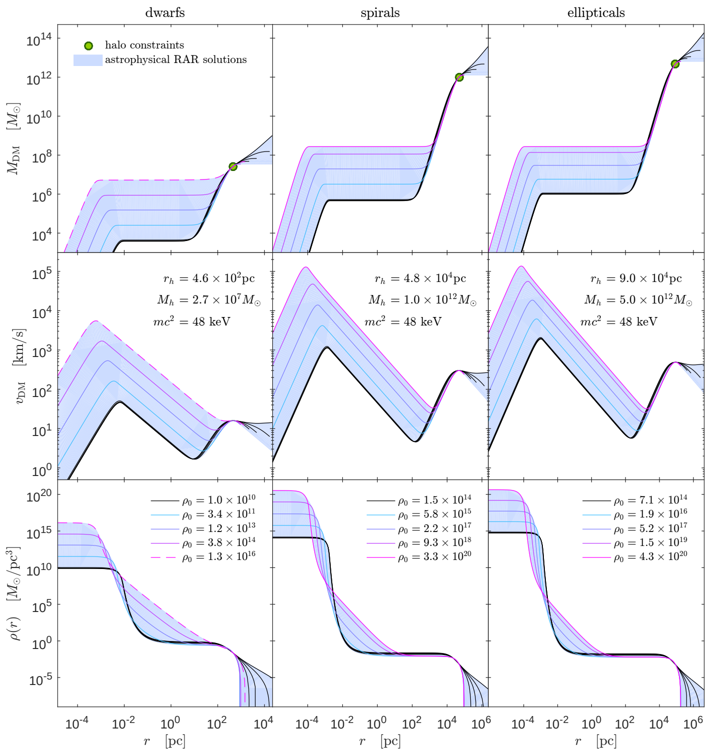

Figure 3.4: (Colour online) Full window of the astrophysical RAR solutions (blue shaded regions enveloped by the 5 benchmark solutions inside), including density profiles (bottom), rotation curves (middle) and DM mass distributions (top); and fulfilling with the observationally given DM halo restriction (r_h, M_h) for typical dwarf (left), spiral (middle) and elliptical galaxies (right), for the relevant case of $mc^2 = 48\,\text{keV}$. The continuous-magenta curves occurring only for spiral and elliptical galaxies, indicates the critical solutions harboring compact critical cores (before collapsing to a BH) of $M_c^{cr} = 2.2 \times 10^8\, M_\odot$, while the dashed-magenta curves for dwarfs are limited (instead) by the astrophysical necessity of a maximum in the halo rotation curve. The bounding black solutions correspond to the ones having the minimum core mass (or minimum ρ_0) which in turn implies the larger cutoff parameters (see Appendix in Argüelles et al. (2016b)), thus developing the more extended density tails allowed by the RAR theory, being $\rho \propto r^{-2}$ the limiting isothermal density tail (achieved when $W_0 \to \infty$).

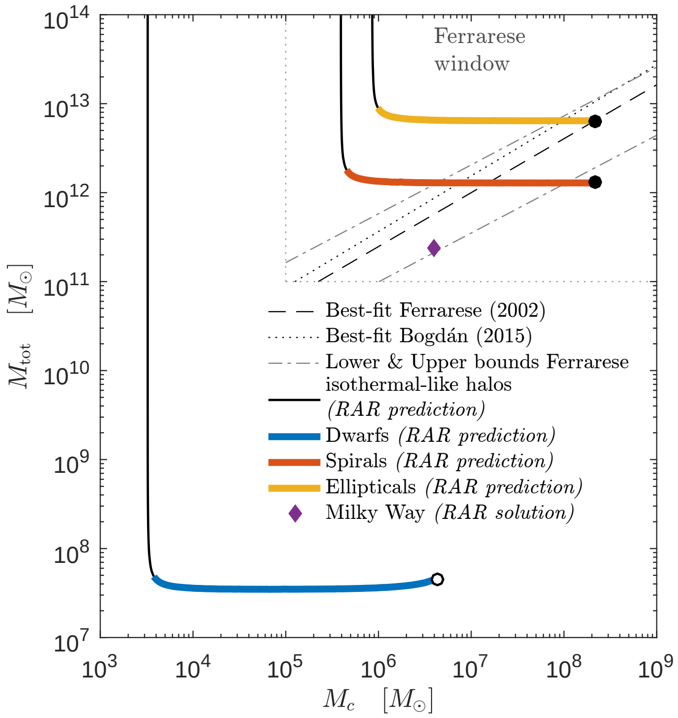

Figure 3.5: (Colour online) The different *predicted* lines read for each galaxy type in correspondence with the astrophysical RAR family of profiles given in 3.4, showing the ability of the three parametric ($mc^2 = 48\,\text{keV}, \theta_0, \beta_0, W_0$) RAR solutions to be in agreement with the different $M_{\rm BH} - M_{\rm tot}$ relations considered in the literature (see text), and explicited in this picture box. While the red and yellow RAR prediction lines, together to the Milky Way solution (i.e. spiral and elliptical galaxies) lay within the 'observable Ferrarese window', the blue RAR prediction for dwarfs, is located at the lower end of the M_c-$M_{\rm tot}$ plane, where data do not support. The filled-black dots correspond to the critical core masses M_c^{cr}, and the empty-black dot indicates the limiting maximum core mass for dwarfs $M_c^{\rm max}$. The black-continuous lines correspond to RAR solutions having the minimum core mass (or minimum ρ_0) which in turn implies the larger cutoff parameters (see Appendic in Argüelles et al. (2016b)), thus developing the more extended and more massive halos.

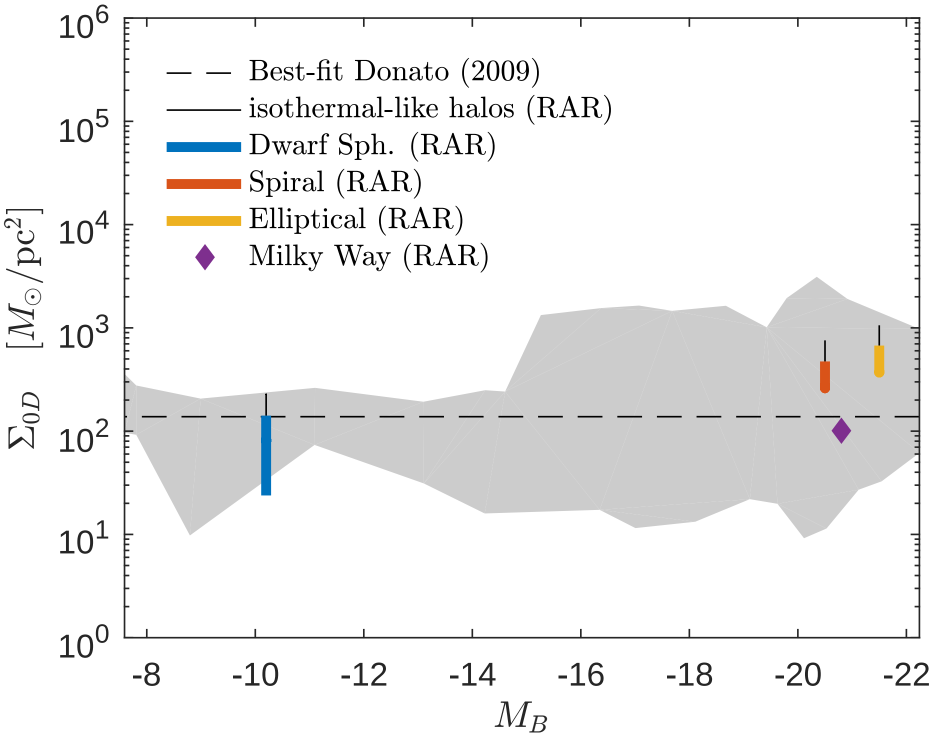

Figure 3.6: (Colour online) The surface DM density as predicted by the RAR model (see vertical colour lines) for each galaxy type in correspondence with the astrophysical RAR family of solutions (i.e. blue-shaded region) given in 3.4. The dashed horizontal line represents the Universal relation as found by Donato et al. (2009) from the best fit of the data. The dark-grey region indicates the delimited area by the $3-\sigma$ error bars of all the data points used in Donato et al. (2009). This result shows the ability of the three parametric (θ_0, β_0, W_0) RAR solutions, for $mc^2 = 48\,\mathrm{keV}$, to be in agreement with the DM surface density observations.

restrictions on the SIDM (total) cross section from using novel observables in merging galactic structures, as well as the rôle of SIDM on the milky way halo and its central region.

4 Publications

4.1 Publications (2017)

1. G.V. Vereshchagin and A. G. Aksenov, "Relativistic Kinetic Theory With Applications in Astrophysics and Cosmology", Cambridge University Press, 2017.

   Relativistic kinetic theory has widespread application in astrophysics and cosmology. The interest has grown in recent years as experimentalists are now able to make reliable measurements on physical systems where relativistic effects are no longer negligible.

   This ambitious monograph is divided into three parts. It presents the basic ideas and concepts of this theory, equations and methods, including derivation of kinetic equations from the relativistic BBGKY hierarchy and discussion of the relation between kinetic and hydrodynamic levels of description. The second part introduces elements of computational physics with special emphasis on numerical integration of Boltzmann equations and related approaches, as well as multi-component hydrodynamics. The third part presents an overview of applications ranging from covariant theory of plasma response, thermalization of relativistic plasma, comptonization in static and moving media to kinetics of self-gravitating systems, cosmological structure formation and neutrino emission during the gravitational collapse.

2. R. Ruffini G. V. Vereshchagin Yu Wang, "Thermal emission in the early afterglow of GRBs from their interaction with supernova ejecta", Astronomy & Astrophysics, Volume 600, id.A131 (2017).

   Context. A thermal X-ray component is observed in the early afterglow of some gamma-ray bursts. Possible explanations include shockwave breakout, relativistic photosphere, or emission from cocoon. The difficulties of these models are discussed. Aims: We propose an alternative model that attributes such a thermal component to the interaction of the gamma-ray burst outflow with a baryonic material near the gamma-ray burst source. Methods: The analytic model is based on relativistic energy-momentum conservation and a diffusion model for photons. The kinematic and observational properties of the supernova ejecta after the interaction are derived. In particular, the temperature and the duration of the thermal emission are obtained. Results: The model is applied to a prototypical GRB 090618 and other gamma-ray bursts associated with supernovae having thermal emission in the early afterglow. The mass of the baryonic material is found to be a few 10-4MŁ, indicating that this material can be a small fraction of the supernova ejecta.

3. R. Ruffini, Y. Wang, Y. Aimuratov, U. Barres de Almeida, L. Becerra, C.L. Bianco, Y.C. Chen, M. Karlica, M. Kovacevic, L. Li, J.D. Melon Fuksman, R. Moradi, M. Muccino, A.V. Penacchioni, G.B. Pisani, D. Primorac, J.A. Rueda, S. Shakeri, G.V. Vereshchagin, S.-S. Xue, "Early X-ray Flares in GRBs", Astrophysical Journal, Volume 852, Issue 1, article id. 53, 27 pp. (2018).

   We analyze the early X-ray flares in the GRB "flare-plateau-afterglow" (FPA) phase observed by Swift-XRT. The FPA occurs only in one of the seven GRB subclasses: the binary-driven hypernovae (BdHNe). This subclass consists of long GRBs with a carbon-oxygen core and a neutron star (NS) binary companion as progenitors. The hypercritical accretion of the supernova (SN) ejecta onto the NS can lead to the gravitational collapse of the NS into a black hole. Consequently, one can observe a GRB emission with isotropic energy $E_{iso} \geq 10^{52}$ erg, as well as the associated GeV emission and the FPA phase. Previous work had shown that gamma-ray spikes in the prompt emission occur at $\sim 10^{15} - 10^{17}$ cm with Lorentz gamma factor $\Gamma \sim 10^2 - 10^3$. Using a novel data analysis we show that the time of occurrence, duration, luminosity and total energy of the X-ray flares correlate with E_{iso}. A crucial feature is the observation of thermal emission in the X-ray flares that we show occurs at radii $\sim 10^{12}$ cm with $\Gamma \leq 4$. These model independent observations cannot be explained by the "fireball" model, which postulates synchrotron and inverse Compton radiation from a single ultra relativistic jetted emission extending from the prompt to the late afterglow and GeV emission phases. We show that in BdHNe a collision between the GRB and the SN ejecta occurs at $\sim 10^{10}$ cm reaching transparency at $\simeq 10^{12}$ cm with $\Gamma \leq 4$. The agreement between the thermal emission observations and these theoretically derived values validates our model and opens the possibility of testing each BdHN episode with the corresponding Lorentz gamma factor.

4. G.V. Vereshchagin, "Photon-photon scattering and absorption of high energy photons in the Universe", Astrophys. Space Sci. (2018), in press; arXiv:1801.02368.

   Photon-photon scattering of gamma-rays on the cosmic microwave background has been studied using the low energy approximation of the total cross section by Zdziarski & Svensson (1989); Svensson & Zdziarski (1990). Here, the cosmic horizon due to photon-photon scattering is accurately determined using the exact cross section and we find that photon-photon scattering dominates over the pair production at energies smaller than 1.68 GeV and at redshifts larger than 180.

5. V.A. Belinski and G.V. Vereshchagin, "On the cosmological gravitational waves and cosmological distances", submitted to Phys. Lett. B, 2017; arXiv:1710.11588.

   We show that solitonic cosmological gravitational waves propagated through the Friedmann universe and generated by the inhomogeneities of the gravitational field near the Big Bang can be responsible for increase of cosmological distances.

6. N. O. Prokopenya, I. A. Siutsou, G. V. Vereshchagin, "Numerical scheme for treatment of Uehling-Uhlenbeck kinetic equation for two-particle interactions in electron-positron-photon plasma", submitted to Journal of Computational Physics, 2017; arXiv:1801.02408.

   We present a new efficient method to compute Uehling-Uhlenbeck collision integral for all two-particle interactions in relativistic plasma with drastic improvement in computation time with respect to existing methods. Plasma is assumed isotropic in momentum space. The set of reactions consists of: Moeller and Bhabha scattering, Compton scattering, two-photon pair annihilation, and two-photon pair production, which are described by QED matrix elements. In our method exact energy and particle number conservation laws are satisfied. Reaction rates are compared, where possible, with the corresponding analytical expressions and convergence of numerical rates is demonstrated.

7. C. R. Argüelles, A. Krut, J. A. Rueda, and R. Ruffini,'Novel constraints on fermionic dark matter from galactic observables', MNRAS, submitted (2017), arXiv: 1606.07040[v2].

   We have recently introduced a new model for the distribution of dark matter (DM) in galaxies, the Ruffini-Argüelles-Rueda (RAR) model, based on a self-gravitating system of massive fermions at finite temperatures. The RAR model, for fermion masses above keV, successfully describes the DM halos in galaxies, and predicts the existence of a denser quantum core towards the centre of each configuration. We demonstrate here, for the first time, that the introduction of a cutoff in the fermion phase-space distribution, necessary to account for the finite Galaxy size, defines a new solution with a compact quantum core which represents an alternative to the central black hole (BH) scenario for SgrA*. For a fermion mass in the range 48 keV$/c^2 \lesssim m \lesssim$ 345 keV$/c^2$, the DM halo distribution fulfills the most recent data of the Milky Way rotation curves, while harbors a dense quantum core of $4 \times 10^6 M_\odot$ within the S2 star pericentre. In particular, for a fermion mass of $m \sim 50$ keV$/c^2$ the model is able to explain the DM halos from typical dwarf spheroidal to normal elliptical galaxies, while harboring dark and massive compact objects from $\sim 10^3 M_\odot$ up to $\sim 10^8 M_\odot$ at their respective centres. The model is shown to be in good agreement with different observationally inferred universal relations, such as the ones connecting DM halos with supermassive dark central objects. Finally, the model provides a natural mechanism for the formation of supermassive BHs as heavy as $M_{\rm BH} \sim$ few $10^8 M_\odot$. We argue that larger BH masses ($M_{\rm BH} \sim 10^{9-10} M_\odot$) may be achieved by assuming subsequent accretion processes onto the above heavy seeds, depending on accretion efficiency and environment.

8. N. E. Mavromatos, C. R. Argüelles, R. Ruffini, and J. A. Rueda, 'Self-interacting dark matter', IJMPD, Volume 26, Issue 3, id. 1730007.

Self-interacting dark matter (SIDM) is a hypothetical form of dark matter (DM), characterised by relatively strong (compared to the weak interaction strength) self-interactions, which has been proposed to resolve a number of issues concerning tensions between simulations and observations at the galactic or smaller scales. We review here some recent developments, based on presentations in the Interacting Dark matter session of the 14th Marcel Grossmann conference, paying particular attention to restrictions on the SIDM (total) cross section from using novel observables in merging galactic structures, as well as the rôle of SIDM on the milky way halo and its central region. We report on some interesting particle-physics inspired SIDM models that have been discussed in the session, namely the glueball DM, and a right-handed neutrino DM (with mass of a few tens of keV, that may exist in minimal extensions of the Standard Model), interacting among themselves via vector bosons mediators in the dark sector. A detailed phenomenology of the latter model on galactic scales, as well as the potential role of the right handed neutrinos in alleviating some of the small-scale cosmology problems, namely the discrepancies between observations and numerical simulations within standard ΛCDM and ΛWDM cosmologies are reported.

4.2 Publications (2005 – 2016)

1. R. Ruffini, G. V. Vereshchagin and S.-S. Xue, "Cosmic absorption of ultra high energy particles", Astrophys. Space Sci. (2016) 361, 82.

   This paper summarizes the limits on propagation of ultra high energy particles in the Universe, set up by their interactions with cosmic background of photons and neutrinos. By taking into account cosmic evolution of these backgrounds and considering appropriate interactions we derive the mean free path for ultra high energy photons, protons and neutrinos. For photons the relevant processes are the Breit-Wheeler process as well as the double pair production process. For protons the relevant reactions are the photopion production and the Bethe-Heitler process. We discuss the interplay between the energy loss length and mean free path for the Bethe-Heitler process. Neutrino opacity is determined by its scattering off the cosmic background neutrino. We compute for the first time the high energy neutrino horizon as a function of its energy.

2. L. G. Gómez, C. R. Argüelles, V. Perlick, J. A. Rueda, and R. Ruffini,'Strong lensing by fermionic dark matter in galaxies', Phys. Rev. D 94, 123004 (2016).

3. C. R. Argüelles, N. E. Mavromatos, J. A. Rueda, and R. Ruffini, 'The role of self-interacting right-handed neutrinos in galactic structure', JCAP, Vol. 4, p. 038 (2016).

4. A. G. Aksenov, R. Ruffini, and G. V. Vereshchagin, "Radiative transfer in relativistic plasma outflows and comptonization of photons near the photosphere", Astronomy Reports, Vol. 59, No. 6, (2015) pp. 418–424.

   We study radiative transfer in plasma by numerical solution of kinetic Boltzmann equations for all particles. We are interested in the thermalization of photons. We considered three cases: 1. The calculations of the timescales of the thermalization in the uniform isotropic plasma. 2. The expansion of the mildly relativistic pair plasma for the mini fireball in the frame of the kinetic approach. 3. The case of ultra relativistically expanding outflow from the surface of the compact object with the Fokker-Planck approximation to the Boltzmann equation for photons. The last case gives the generalized Kompaneets equation which takes into account anisotropic distribution of photons developed near the photosphere. For the electron temperature dependence from radius $T \propto r^{-2}$and thermal electrons spectrum we found the low-energy photon index can be $\lesssim 0.5$as typically observed in GRB.

5. G. V. Vereshchagin, "Physics of Non-Dissipative Ultrarelativistic Photospheres", in Proceedings of the MG13 Meeting on General Relativity, eds. Rosquist et al., WSPC (2015) pp. 708-728.

   Recent observations, especially by the Fermi satellite, point out the importance of the thermal component in GRB spectra. This fact revives strong interest in photospheric emission from relativistic outflows. Early studies already suggested that the observed spectrum of photospheric emission from relativistically moving objects differs in shape from the Planck spectrum. However, this component appears to be subdominant in many GRBs and the origin of the dominant component is still unclear. One of the popular ideas is that energy dissipation near the photosphere may produce a non-thermal spectrum and account for such emission. Before considering such models, though, one has to determine precise spectral and timing characteristics of the photospheric emission in the simplest possible case. Hence this paper focuses on various physical effects which make the photospheric emission spectrum different from the black body spectrum and quantifies them.

6. R. Ruffini, I.A. Siutsou and G.V. Vereshchagin, "Photon Thick and Photon Thin Relativistic Outflows and GRBs", in Proceedings of the MG13 Meeting on General Relativity, eds. Rosquist et al., WSPC (2015) pp. 1748-1750.

   A new physically motivated classification of outflows with respect to the photospheric emission–photon thick and photon thin outflows–is proposed. We computed both energy flux and observed spectra in dynamics. For photon thick outflows these results generalize the ones known for steady relativistic winds. In photon thin outflows most of radiation is shown to originate not at its photospheric radius, but at smaller radii due to radiation diffusion. Time integrated observed spectra are naturally described by the Band function. For our simple density profile and thermal comoving emission we find values for the low energy power law index $\alpha \simeq 0.2 \div 1$and the high-energy power law index $\beta \simeq -3.5$.

7. A.G. Aksenov, R. Ruffini and G.V. Vereshchagin, "Radiative Transfer Near the Photosphere of Mildly and Ultrarelativistic Outflows", in Proceedings of the MG13 Meeting on General Relativity, eds. Rosquist et al., WSPC (2015) pp. 1754-1756.

   We study radiation transport in the pair plasma of GRB sources. We considered two cases. 1. Mildly reletivistic plasma with a final gamma factor $\lesssim 10$of a mini fireball reaches a thermal equilibrium at it expands. We use kinetic approach for all particles without additional assumptions. 2. Ultra relativistic plasma corresponding to real GRB. We assume thermal spectra for electrons in the comoving reference frame (CRF). We obtained the nonthermal spectrum of photons.

8. D. Bégué, I.A. Siutsou and G.V. Vereshchagin, "On the Decoupling of Photons from Relativistically Expanding Outflows", in Proceedings of the MG13 Meeting on General Relativity, eds. Rosquist et al., WSPC (2015) pp. 1760-1761.

   We studied the decoupling of photons from ultra-relativistic spherically symmetric outflows expanding with constant velocity by means of Monte-Carlo (MC) simulation. We compute and analyse the probability density function of photon last scattering.

9. I. A. Siutsou, A. G. Aksenov and G. V. Vereshchagin, "On Thermalization of Electron-Positron-Photon Plasma", AIP Conf. Proc. 1693 (2015) 070007.

   Recently a progress has been made in understanding thermalization mechanism of relativistic plasma starting from a non-equilibrium state. Relativistic Boltzmann equations were solved numerically for homogeneous isotropic plasma with collision integrals for two- and three-particle interactions calculated from the first principles by means of QED matrix elements. All particles were assumed to fulfill Boltzmann statistics. In this work we follow plasma thermalization by accounting for Bose enhancement and Pauli blocking in particle interactions. Our results show that particle in equilibrium reach Bose-Einstein distribution for photons, and Fermi-Dirac one for electrons, respectively.

10. R. Ruffini, C. R. Argüelles and J. A. Rueda, "On the core-halo distribution of dark matter in galaxies" MNRAS, 451 (2015) 622.

    We investigate the distribution of dark matter in galaxies by solving the equations of equilibrium of a self-gravitating system of massive fermions ('inos') at selected temperatures and degeneracy parameters within general relativity. Our most general solutions show, as a function of the radius, a segregation of three physical regimes: 1) an inner core of almost constant density governed by degenerate quantum statistics; 2) an intermediate region with a sharply decreasing density distribution followed by an extended plateau, implying quantum corrections; 3) an asymptotic, $\rho \propto r^{-2}$ classical Boltzmann regime fulfilling, as an eigenvalue problem, a fixed value of the flat rotation curves. This eigenvalue problem determines, for each value of the central degeneracy parameter, the mass of the ino as well as the radius and mass of the inner quantum core. Consequences of this alternative approach to the central and halo regions of galaxies, ranging from dwarf to big spirals, for SgrA*, as well as for the existing estimates of the ino mass, are outlined.

11. I. Siutsou, C. R. Argüelles and R. Ruffini, "Dark matter massive fermions and Einasto profiles in galactic halos", Astron. Rep. 59 No. 7 (2015) 656.

    On the basis of a fermionic dark matter model we fit rotation curves of The HI Nearby Galaxy Survey (THINGS) sample and compare our 3-parametric model to other models widely used in the literature: 2-parametric Navarro–Frenk–White, pseudoisothermal sphere, Burkhert models, and 3-parametric Einasto model, suggested as the new "standard dark matter profile" model in the paper by Chemin et al., Astron. J. 142 (2011) 109. The results from the fitting procedure provides evidence for an underlying fermionic nature of the dark matter candidate, with rest mass above the keV regime.

12. C. R. Argüelles and R. Ruffini, "A regular and relativistic Einstein cluster within the S2 orbit centered in SgrA*" The Thirteenth Marcel Grossmann Meeting Book, Vol. B (2015) 1734.

    In 1939 Einstein [1] provided a model of self-gravitating masses, each moving along geodesic circular orbits under the influence of the gravitational field of the rest of the particle in the system. This model allowed him to argue that 'Schwarzschild singularities' do not exist in physical reality because a cluster with a given number of masses cannot be arbitrarily concentrated. This is due to the fact that otherwise the particles constituting the cluster would reach the speed of light. Of course, this model can actually only be considered as an interesting possibility to try to provide a counterexample of a singularity within Einstein's theory of gravity, since Black Holes are a physical reality within the theory of General Relativity.

13. B. M. O. Fraga, C. R. Argüelles, R. Ruffini and I. Siutsou, "Semidegenerate self-gravitating system of fermion as Dark Matter on galaxies I: Universality laws", The Thirteenth Marcel Grossmann Meeting Book, Vol. B (2015) 1730.

    We present a unified model for galactic Dark Matter (DM) halos as well as galactic DM central cores (alternatively to the central Supermassive Black Hole scenario), based on systems of self-gravitating fermions at finite temperatures. This work will deal mainly with the halo part, leaving the core description to another part of this proceedings.

14. G.V. Vereshchagin, "Relativistic Kinetic Theory with some Applications", in: Cosmology and Gravitation: XVth Brazilian School of Cosmology and Gravitation, eds. Mario Novello and Santiago E.Perez Bergliaffa, Cambridge Scientific Publishers, 2014, pp 1-40.

    A brief introduction into relativistic kinetic theory is given. Some applications of this theory in plasma physics, astrophysics and cosmology are reviewed.

15. D. Begue and G.V. Vereshchagin, "Transparency of an instantaneously created electron-positron-photon plasma", MNRAS, Vol. 439 (2014), pp. 924-928.

    The problem of the expansion of a relativistic plasma generated when a large amount of energy is released in a small volume has been considered by many authors. We use the analytical solution of Bisnovatyi-Kogan and Murzina for the spherically symmetric relativistic expansion. The light curves and the spectra from transparency of an electron-positron-photon plasma are obtained. We compare our results with the work of Goodman.

16. I.A. Siutsou and G.V. Vereshchagin, "Relativistic spotlight ", Physics Letters B, Volume 730 (2014), pp. 190â€"192.

    Relativistic motion gives rise to a large number of interesting and sometimes counterintuitive effects. In this work we consider an example of such effects, which we term relativistic spotlight. When an isotropic source of soft photons with proper intensity I_0 is placed at rest between a distant observer and photosphere of relativistic wind, its intensity as seen by the observer gets enhanced up to $\sim \Gamma^4 I_0$, where Γ is bulk Lorentz factor of the wind. In addition, these photons may extract a large part of the wind kinetic energy. We speculate that such effect may be relevant for the physics of GRBs.

17. G.V. Vereshchagin, "Physics of non-dissipative ultrarelativistic photospheres ", International Journal of Modern Physics D Vol. 23, No. 1 (2014) 1430003.

    Recent observations, especially by the Fermi satellite, point out the importance of the thermal component in GRB spectra. This fact revives strong interest in photospheric emission from relativistic outflows. Early studies already suggested that the observed spectrum of photospheric emission from relativistically moving objects differs in shape from the Planck spectrum. However, this component appears to be subdominant in many GRBs and the origin of the dominant component is still unclear. One of the popular ideas is that energy dissipation near the photosphere may produce a nonthermal spectrum and account for such emission. Before considering such models, though, one has to determine precise spectral and timing characteristics of the photospheric emission in the simplest possible case. Hence this paper focuses on various physical effects which make the photospheric emission spectrum different from the black body spectrum and quantifies them.

18. I.A. Siutsou, R. Ruffini and G.V. Vereshchagin, "Spreading of ultrarelativistically expanding shell: an application to GRBs", New Astronomy, Vol. 27 (2014), pp. 30-33.

    Optically thick energy dominated plasma created in the source of Gamma-Ray Bursts (GRBs) expands radially with acceleration and forms a shell with constant width measured in the laboratory frame. When strong Lorentz factor gradients are present within the shell it is supposed to spread at sufficiently large radii. There are two possible mechanisms of spreading: hydrodynamical and thermal ones. We consider both mechanisms evaluating the amount of spreading that occurs during expansion up to the moment when the expanding shell becomes transparent for photons. We compute the hydrodynamical spreading of an ultrarelativistically expanding shell. In the case of thermal spreading we compute the velocity spread as a function of two parameters: comoving temperature and bulk Lorentz factor of relativistic Maxwellian distribution. Based on this result we determine the value of thermal spreading of relativistically expanding shell. We found that thermal spreading is negligible for typical GRB parameters. Instead hydrodynamical spreading appears to be significant, with the shell width reaching $\sim 10^{10}$ cm for total energy $E = 10^{54}$ erg and baryonic loading $B = 10^{-2}$. Within the fireshell model such spreading will result in the duration of Proper Gamma-Ray Bursts up to several seconds.

19. G.V.Vereshchagin, "Relativistic Kinetic Theory with some Applications", in: Cosmology and Gravitation: XVth Brazilian School of Cosmology and Gravitation, eds. Mario Novello and Santiago E.Perez Bergliaffa, Cambridge Scientific Publishers, 2014, pp 1-40.

    A brief introduction into relativistic kinetic theory is given. Some applications of this theory in plasma physics, astrophysics and cosmology are reviewed.

20. A. Benedetti, R. Ruffini and G.V. Vereshchagin, "Evolution of the pair plasma generated by a strong electric field", Physics Letters A, Volume 377 (2013), Issue 3-4, p. 206-215.

    We study the process of energy conversion from overcritical electric field into electron-positron-photon plasma. We solve numerically Vlasov-Boltzmann equations for pairs and photons assuming the system to be homogeneous and anisotropic. All the 2-particle QED interactions between pairs and photons are described by collision terms. We evidence several epochs of this energy conversion, each of them associated to a specific physical process. Firstly pair creation occurs, secondly back reaction results in plasma oscillations. Thirdly photons are produced by electron-positron annihilation. Finally particle interactions lead to completely equilibrated thermal electron-positron-photon plasma.

21. D. Begue, I. A. Siutsou and G. V. Vereshchagin, "Monte Carlo simulations of the photospheric emission in GRBs", the Astrophysical Journal Volume 767 (2013), Issue 2, article id. 139.

    We studied the decoupling of photons from ultra-relativistic spherically symmetric outflows expanding with constant velocity by means of Monte Carlo simulations. For outflows with finite widths we confirm the existence of two regimes: photon-thick and photon-thin, introduced recently by Ruffini et al. (RSV). The probability density function of the last scattering of photons is shown to be very different in these two cases. We also obtained spectra as well as light curves. In the photon-thick case, the time-integrated spectrum is much broader than the Planck function and its shape is well described by the fuzzy photosphere approximation introduced by RSV. In the photon-thin case, we confirm the crucial role of photon diffusion, hence the probability density of decoupling has a maximum near the diffusion radius well below the photosphere. The time-integrated spectrum of the photon-thin case has a Band shape that is produced when the outflow is optically thick and its peak is formed at the diffusion radius.

22. R. Ruffni, I. A. Siutsou and G. V. Vereshchagin, "Theory of photospheric emission from relativistic outflows" , the Astrophysical Journal, Vol. 772, Issue 1 (2013) article id. 11.

    We derive the optical depth and photospheric radius of relativistic outflow using the model of relativistic wind with finite duration. We also discuss the role of radiative diffusion in such outflow. We solve numerically radiative transfer equation and obtain light curves and observed spectra of photospheric emission. The obtained spectra are nonthermal and in some cases have Band shape.

23. R. Ruffini and G.V. Vereshchagin, "Electron-positron plasma in GRBs and in cosmology", Il Nuovo Cimento C 36 (2013) 255.

    Electron-positron plasma is believed to play imporant role both in the early Universe and in sources of Gamma-Ray Bursts (GRBs). We focus on analogy and difference between physical conditions of electron-positron plasma in the early Universe and in sources of GRBs. We discuss a) dynamical differences, namely thermal acceleration of the outflow in GRB sources vs cosmological deceleration; b) nuclear composition differences as synthesis of light elements in the early Universe and possible destruction of heavy elements in GRB plasma; c) different physical conditions during last scattering of photons by electrons. Only during the acceleration phase of the optically thick electron-positron plasma comoving observer may find it similar to the early Universe. This similarity breaks down during the coasting phase. Reprocessing of nuclear abundances may likely take place in GRB sources. Heavy nuclear elements are then destroyed, resulting mainly in protons with small admixture of helium. Unlike the primordial plasma which recombines to form neutral hydrogen, and emits the Cosmic Microwave Background Radiation, GRB plasma does not cool down enough to recombine.

24. A.G. Aksenov, R. Ruffni and G. V. Vereshchagin, "Comptonization of

photons near the photosphere of relativistic outflows", MNRAS Letters, Vol. 436, Issue 1 (2013) pp. L54-L58.

We consider the formation of photon spectrum at the photosphere of ultra-relativistically expanding outflow. We use the Fokker–Planck approximation to the Boltzmann equation, and obtain the generalized Kompaneets equation which takes into account anisotropic distribution of photons developed near the photosphere. This equation is solved numerically for relativistic steady wind and the observed spectrum is found in agreement with previous studies. We also study the photospheric emission for different temperature dependences on radius in such outflows. In particular, we found that for $T \propto r^{-2}$ the Band low-energy photon index of the observed spectrum is $\simeq -1$, as typically observed in Gamma-Ray Bursts.

25. R. Ruffini, C. R. Argüelles, B. M. O. Fraga, A. Geralico, H. Quevedo, J. A. Rueda, I. Siutsou, "Black Holes in Gamma Ray Bursts and Galactic Nuclei", IJMPD 22 No. 11, 1360008, 2013.

    Current research marks a clear success in identifying the moment of formation of a Black Hole of $10M_\odot$, with the emission of a Gamma Ray Burst. This explains in terms of the 'Blackholic Energy' the source of the energy of these astrophysical systems. Their energetics up to 10^{54} erg, make them detectable all over our Universe. Concurrently a new problematic has been arising related to: (a) The evidence of Dark Matter in galactic halos; (b) The origin of the Super Massive Black Holes in active galactic nuclei and Quasars and (c) The purported existence of a Black Hole in the Center of our Galaxy. These three aspects of this new problematic have been traditionally approached independently. We propose an unified approach to all three of them based on a system of massive self-gravitating neutrinos in General Relativity. Perspectives of future research are presented.

26. C. R. Argüelles, I. Siutsou, R. Ruffini, J. A. Rueda, B. Machado, "On the core-halo constituents of a semi-degenerate gas of massive fermions" AAS, Probes of Dark Matter on Galaxy Scales, 45, 30204, 2013.

    We propose a model of self-gravitating bare fermions at finite temperature in General Relativity to describe the dark matter (DM) in galaxies. We obtain a universal density profile composed by a flat and fully degenerate core for small radii, a low-degenerate plateau and a Newtonian tail that scales with r^{-2} for the outer halo region. The free parameters of the model are fitted using galactic observables such as the constant rotation velocity, mass of the central object and the halo radius, concluding that the particle mass should be in the keV range. We further show that thighter constraints of a few keV for the mass of the fermions are obtained when using typical smallest dwarf galaxies.

27. B. M. O. Fraga, C. R. Argüelles, R. Ruffini, ”Self-Gravitating System of Semidegenerated Fermions as Central Objects and Dark Matter Halos in Galaxies”, IJMPS 23, 357-362, 2013.

    We propose a unified model for dark matter haloes and central galactic objects as a self-gravitating system of semidegenerated fermions in thermal equilibrium. We consider spherical symmetry and then we solve the equations of gravitational equilibrium using the Fermi integrals in a dimensionless manner, obtaining the density profile and velocity curve. We also obtain scaling laws for the observables of the system and show that, for a wide range of our parameters, our model is consistent with the so called universality of the surface density of dark matter.

28. Micol Benetti, S. Pandolfi, M. Lattanzi, M.Martinelli, A. Melchiorri. “Featuring the primordial power spectrum: new constraints on interrupted slow-roll from CMB and LRG data ”, Physical Review D (2013) vol. 87, Issue 2, id. 023519

    Using the most recent data from the WMAP, ACT and SPT experiments, we update the constraints on models with oscillatory features in the primordial power spectrum of scalar perturbations. This kind of features can appear in models of inflation where slow-roll is interrupted, like multifield models. We also derive constraints for the case in which, in addition to cosmic microwave observations, we also consider the data on the spectrum of luminous red galaxies from the 7th SDSS catalog, and the SNIa Union Compilation 2 data. We have found that: (i) considering a model with features in the primordial power spectrum increases the agreement with data with the respect of the featureless “vanilla” ΛCDM model by $\Delta\chi^2 \simeq 7$; (ii) the uncertainty on the determination of the standard parameters is not degraded when features are included; (iii) the best fit for the features model locates the step in the primordial spectrum at a scale $k \simeq 0.005$ Mpc^{-1}, corresponding to the scale where the outliers in the WMAP7 data at $\ell = 22$ and $\ell = 40$ are located.; (iv) a distinct, albeit less statistically significant peak is present in the likelihood at smaller scales, with a $\Delta\chi^2 \simeq 3.5$, whose presence might be related to the WMAP7 preference for a negative value of the running of the scalar spectral index parameter; (v) the inclusion of the LRG-7 data do not change significantly the best fit model, but allows to better constrain the amplitude of the oscillations.

29. M. Benetti, M. Gerbino, W. H. Kinney, E. W. Kolb, M. Lattanzi, A. Melchiorri, L. Pagano, A. Riotto. "Cosmological data and indications for new physics", Journal of Cosmology and Astroparticle Physics, 10 (2013) 030.

    Data from the Atacama Cosmology Telescope (ACT) and the South Pole Telescope (SPT), combined with the nine-year data release from the WMAP satellite, provide very precise measurements of the cosmic microwave background (CMB) angular anisotropies down to very small angular scales. Augmented with measurements from Baryonic Acoustic Oscillations surveys and determinations of the Hubble constant, we investigate whether there are indications for new physics beyond a Harrison-Zel'dovich model for primordial perturbations and the standard number of relativistic degrees of freedom at primordial recombination. All combinations of datasets point to physics beyond the minimal Harrison-Zel'dovich model in the form of either a scalar spectral index different from unity or additional relativistic degrees of freedom at recombination (e.g., additional light neutrinos). Beyond that, the extended datasets including either ACT or SPT provide very different indications: while the extended-ACT (eACT) dataset is perfectly consistent with the predictions of standard slow-roll inflation, the extended-SPT (eSPT) dataset prefers a non-power-law scalar spectral index with a very large variation with scale of the spectral index. Both eACT and eSPT favor additional light degrees of freedom. eACT is consistent with zero neutrino masses, while eSPT favors nonzero neutrino masses at more than 95% confidence.

30. M. Benetti. "Updating constraints by Planck data on inlationary features model", Physical Review D 88 (2013) 087302.

    We present new constraints on possible features in the primordial inflationary density perturbations power spectrum in light of the recent Cosmic Microwave Background Anisotropies measurements from the Planck satellite. We found that the Planck data hints for the presence of features in two different ranges of angular scales, corresponding to multipoles $10 < l < 60$ and $150 < l < 300$, with a decrease in the best fit χ^2 value with respect to the featureless "vanilla" LCDM model of $\Delta\chi^2$ around 9 in both cases.

31. B. Patricelli, M.G. Bernardini, C.L. Bianco, L. Caito, G. de Barros, L.

Izzo, R. Ruffini and G.V. Vereshchagin, "Analysis of GRB 080319B and GRB 050904 within the Fireshell Model: Evidence for a Broader Spectral Energy Distribution", The Astrophysical Journal, Volume 756, Issue 1, article id. 16 (2012).

The observation of GRB 080319B, with an isotropic energy $E_{iso}= 1.32 \times 10^{54}$ erg, and GRB 050904, with $E_{iso}= 1.04 \times 10^{54}$ erg, offers the possibility of studying the spectral properties of the prompt radiation of two of the most energetic gamma-ray bursts (GRBs). This allows us to probe the validity of the fireshell model for GRBs beyond 10^{54} erg, well outside the energy range where it has been successfully tested up to now (10^{49}-10^{53}erg). We find that in the low-energy region, the prompt emission spectra observed by Swift Burst Alert Telescope (BAT) reveals more power than theoretically predicted. The opportunities offered by these observations to improve the fireshell model are outlined in this paper. One of the distinguishing features of the fireshell model is that it relates the observed GRB spectra to the spectrum in the comoving frame of the fireshell. Originally, a fully radiative condition and a comoving thermal spectrum were adopted. An additional power law in the comoving thermal spectrum is required due to the discrepancy of the theoretical and observed light curves and spectra in the fireshell model for GRBs 080319B and 050904. A new phenomenological parameter α is correspondingly introduced in the model. We perform numerical simulations of the prompt emission in the Swift BAT bandpass by assuming different values of within the fireshell model. We compare them with the GRB 080319B and GRB 050904 observed time-resolved spectra, as well as with their time-integrated spectra and light curves. Although GRB 080319B and GRB 050904 are at very different redshifts ($z = 0.937$ and $z = 6.29$, respectively), a value of $\alpha = -1.8$ for both of them leads to a good agreement between the numerical simulations and the observed BAT light curves, time-resolved and time-integrated spectra. Such a modified spectrum is also consistent with the observations of previously analyzed less energetic GRBs and reasons for this additional agreement are given. Perspectives for future low-energy missions are outlined.

32. A.G. Aksenov, R. Ruffni, I. A. Siutsou and G. V. Vereshchagin, "Dynamics and emission of mildly relativistic plasma", International Journal of Modern Physics: Conference Series, Vol. 12, Issue 01, (2012) pp. 1-9.

Initially optically thick (with $\tau = 3 \times 10^7$) spherically symmetric outflow consisting of electron-positron pairs and photons is considered. We do not assume thermal equilibrium, and include the two-body processes that occur in such plasma: Moller and Bhaba scattering of pairs, Compton scattering, two-photon pair annihilation, two-photon pair production, together with their radiative three-body variants: bremsstrahlung, double Compton scattering, and three-photon pair annihilation, with their inverse processes. We solve numerically the relativistic Boltzmann equations in spherically symmetric case for distribution functions of pairs and photons. Three epochs are considered in details: a) the thermalization, which brings initially nonequilibrium plasma to thermal equilibrium; b) the self-accelerated expansion, which we find in agreement with previous hydrodynamic studies and c) decoupling of photons from the expanding electron-positron plasma. Photon spectra are computed, and appear to be non thermal near the peak of the luminosity. In particular, the low energy part of the spectrum contain more power with respect to the black body one.

33. A. Benedetti, W.-B. Han, R. Ruffini and G.V. Vereshchagin, "On the frequency of oscillations in the pair plasma generated by a strong electric field", Physics Letters B, Vol. 698 (2011) 75-79.

    We study the frequency of the plasma oscillations of electron-positron pairs created by the vacuum polarization in a uniform electric field with strength E in the range $0.2E_c < E < 10E_c$. Following the approach adopted in Ruffini et al. (2007) we work out one second order ordinary differential equation for a variable related to the velocity from which we can recover the classical plasma oscillation equation when E→0. Thereby, we focus our attention on its evolution in time studying how this oscillation frequency approaches the plasma frequency. The time-scale needed to approach to the plasma frequency and the power spectrum of these oscillations are computed. The characteristic frequency of the power spectrum is determined uniquely from the initial value of the electric field strength. The effects of plasma degeneracy and pair annihilation are discussed.

34. B. Patricelli, M.G. Bernardini, C.L. Bianco, L. Caito, L. Izzo, R. Ruffini and G.V. Vereshchagin, "A New Spectral Energy Distribution of Photons in the Fireshell Model of GRBs", International Journal of Modern Physics D, Vol. 20 (2011) 1983-1987.

    The analysis of various Gamma-Ray Bursts (GRBs) having a low energetics within the fireshell model has shown how the N(E) spectrum of their prompt emission can be reproduced in a satisfactory way by a convolution of thermal spectra. Nevertheless, from the study of very energetic bursts such as, for example, GRB 080319B, some discrepancies between the numerical simulations and the observational data have been observed. We investigate a different spectrum of photons in the comoving frame of the fireshell in order to better reproduce the spectral properties of GRB prompt emission within the fireshell model. We introduce a phenomenologically modified thermal spectrum: a thermal spectrum characterized by a different asymptotic power-law index in the low energy region. Such an index depends on a free parameter α, so that the pure thermal spectrum corresponds to the case $\alpha = 0$. We test this spectrum by comparing the numerical simulations with the observed prompt emission spectra of various GRBs. From this analysis it has emerged that the observational data can be correctly reproduced by assuming a modified thermal spectrum with $\alpha = -1.8$.

35. Elena Giusarma, Martina Corsi, Maria Archidiacono, Roland de Putter, Alessandro Melchiorri, Olga Mena, Stefania Pandolfi. "Constraints on massive sterile neutrino species from current and future cosmological data", Phys.Rev. D83, 115023 (2011)

    Sterile massive neutrinos are a natural extension of the standard model of elementary particles. The energy density of the extra sterile massive states affects cosmological measurements in an analogous way to that of active neutrino species. We perform here an analysis of current cosmological data and derive bounds on the masses of the active and the sterile neutrino states, as well as on the number of sterile states. The so-called (3+2) models, with three sub-eV active massive neutrinos plus two sub-eV massive sterile species, is well within the 95% CL allowed regions when considering cosmological data only. If the two extra sterile states have thermal abundances at decoupling, big bang nucleosynthesis bounds compromise the viability of (3+2) models. Forecasts from future cosmological data on the active and sterile neutrino parameters are also presented. Independent measurements of the neutrino mass from tritium beta-decay experiments and of the Hubble constant could shed light on sub-eV massive sterile neutrino scenarios.

36. M. Archidiacono, A. Melchiorri, S. Pandolfi, "The impact of Reionization modelling on CMB Neutrino Mass Bounds", Nuclear Physics B, Proceedings Supplements, Volume 217, Issue 1, p. 65-67. (2011)

    We investigate the bounds on the neutrino mass in a general reionization scenario based on a principal component approach. We found the constraint on the sum of the neutrino masses from CMB data can be relaxed by a ~ 40 % in a generalized reionization scenario.

37. Erminia Calabrese, Eloisa Menegoni, C. J. A. P. Martins, Alessandro Melchiorri, and Graca Rocha, "Constraining variations in the fine structure constant in the presence of early dark energy", Phys.Rev. D84 (2011) 023518.

    We discuss present and future cosmological constraints on variations of the fine structure constant α induced by an early dark energy component having the simplest allowed (linear) coupling to electromagnetism. We find that current cosmological data show no variation of the fine structure constant at recombination respect to the present-day value, with $\alpha/\alpha_0 = 0.975 \pm 0.020$ at 95% c.l., constraining the energy density in early dark energy to $\Omega_e < 0.060$ at 95% c.l. Moreover, we consider constraints on the parameter quantifying the strength of the coupling by the scalar field. We find that current cosmological constraints on the coupling are about 20 times weaker than those obtainable locally (which come from Equivalence Principle tests). However forthcoming or future missions, such as Planck Surveyor and CMBPol, can match and possibly even surpass the sensitivity of current local tests.

38. Micol Benetti, Massimiliano Lattanzi, Erminia Calabrese, Alessandro Melchiorri, "Features in the primordial spectrum: new constraints from WMAP7+ACT data and prospects for Planck", Phys. Rev. D 84, 063509 (2011)

    We update the constraints on possible features in the primordial inflationary density perturbation spectrum by using the latest data from the WMAP7 and ACT Cosmic Microwave Background experiments. The inclusion of new data significantly improves the constraints with respect to older work, especially to smaller angular scales. While we found no clear statistical evidence in the data for extensions to the simplest, featureless, inflationary model, models with a step provide a significantly better fit than standard featureless power-law spectra. We show that the possibility of a step in the inflationary potential like the one preferred by current data will soon be tested by the forthcoming temperature and polarization data from the Planck satellite mission.

39. Stefania Pandolfi, Elena Giusarma, Edward W. Kolb, Massimiliano Lattanzi, Alessandro Melchiorri, Olga Mena, Manuel Pena, Asantha

Cooray, Paolo Serra, ”Impact of general reionization scenarios on extraction of inflationary parameters”, Phys.Rev. D82, 123527, (2010).

Determination of whether the Harrison–Zel'dovich spectrum for primordial scalar perturbations is consistent with observations is sensitive to assumptions about the reionization scenario. In light of this result, we revisit constraints on inflationary models using more general reionization scenarios. While the bounds on the tensor-to-scalar ratio are largely unmodified, when different reionization schemes are addressed, hybrid models are back into the inflationary game. In the general reionization picture, we reconstruct both the shape and amplitude of the inflaton potential. We find a broader spectrum of potential shapes when relaxing the simple reionization restriction. An upper limit of 10^{16} GeV to the amplitude of the potential is found, regardless of the assumptions on the reionization history.

40. A.G. Aksenov, R. Ruffini and G.V. Vereshchagin, “Pair plasma relaxation time scales”, Physical Review E, Vol. 81 (2010) 046401.

    By numerically solving the relativistic Boltzmann equations, we compute the time scale for relaxation to thermal equilibrium for an optically thick electron-positron plasma with baryon loading. We focus on the time scales of electromagnetic interactions. The collisional integrals are obtained directly from the corresponding QED matrix elements. Thermalization time scales are computed for a wide range of values of both the total energy density (over 10 orders of magnitude) and of the baryonic loading parameter (over 6 orders of magnitude). This also allows us to study such interesting limiting cases as the almost purely electron-positron plasma or electron-proton plasma as well as intermediate cases. These results appear to be important both for laboratory experiments aimed at generating optically thick pair plasmas as well as for astrophysical models in which electron-positron pair plasmas play a relevant role.

41. R. Ruffini, G.V. Vereshchagin and S.-S. Xue, “Electron-positron pairs in physics and astrophysics: from heavy nuclei to black holes” Physics Reports, Vol. 487 (2010) No 1-4, pp. 1-140.

    From the interaction of physics and astrophysics we are witnessing in these years a splendid synthesis of theoretical, experimental and observational results originating from three fundametal physical processes. They were originally proposed by Dirac, by Breit and Wheeler and by Sauter, Heisenberg, Euler and Schwinger. For almost seventy years they have all three been followed by a continued effort of experimental verification on Earth-based experiments. The Dirac process, $e^+e^- \to 2\gamma$, has been by far the most successful. It has obtained extremely accurate experimental verification and has led as well to an enormous number of new physics in possibly one of the most fruitful experimental avenue by introduction of storage rings in Frascati and followed by the largest accelerators worldwide: DESY, SLAC etc. The Breit-Wheeler process, $2\gamma \to e^+e^-$, although conceptually simple, being the inverse process of the Dirac one, has been by far one of the most difficult to be verified experimentally. Only recently, through the technology based on free electron X-ray laser and its numerous applications in Earth-based experiments, some first indications of its possible verification have been reached. The vacuum polarization process in strong electromagnetic field, pioneered by Sauter, Heisenberg, Euler and Schwinger, introduced the concept of critical electric field $E_c = m_e^2c^3/e\hbar$. It has been searched without success for more than forty years by heavy-ion collisions in many of the leading particle accelerators worldwide. The novel situation today is that these same processes can be studied on a much more grandiose scale during the gravitational collapse leading to the formation of a black hole being observed in Gamma Ray Bursts (GRBs). This report is dedicated to the scientific race in act. The theoretical and experimental work developed in Earth-based laboratories is confronted with the theoretical interpretation of space-based observations of phenomena originating on cosmological scales. What has become clear in the last ten years is that all the three above mentioned processes, duly extended in the general relativistic framework, are necessary for the understanding of the physics of the gravitational collapse to a black hole. Vice versa, the natural arena where these processes can be observed in mutual interaction and on an unprecedented scale, is indeed the realm of relativistic astrophysics. We systematically analyze the conceptual developments which have followed the basic work of Dirac and Breit-Wheeler. We also recall how the seminal work of Born and Infeld inspired the work by Sauter, Heisenberg and Euler on effective Lagrangian leading to the estimate of the rate for the process of electron-positron production in a constant electric field. In addition of reviewing the intuitive semi-classical treatment of quantum mechanical tunneling for describing the process of electron-positron production, we recall the calculations in *Quantum Electro-Dynamics* of the Schwinger rate and effective Lagrangian for constant electromagnetic fields. We also review the electron-positron production in both time-alternating electromagnetic fields, studied by Brezin, Itzykson, Popov, Nikishov and Narozhny, and the corresponding processes relevant for pair production at the focus of coherent laser beams as well as electron beam-laser collision. We finally report some current developments based on the general JWKB approach which allows to compute the Schwinger rate in spatially varying and time varying electromagnetic fields. We also recall the pioneering work of Landau and Lifshitz, and Racah on the collision of charged particles as well as experimental success of AdA and ADONE in the production of electron-positron pairs. We then turn to the possible experimental verification of these phenomena. We review: A) the experimental verification of the $e^+e^- \rightarrow 2\gamma$ process studied by Dirac. We also briefly recall the very successful experiments of e^+e^- annihilation to hadronic channels, in addition to the Dirac electromagnetic channel; B) ongoing Earth based experiments to detect electron-positron production in strong fields by focusing coherent laser beams and by electron beam-laser collisions; and C) the multiyear attempts to detect electron-positron production in Coulomb fields for a large atomic number $Z > 137$ in heavy ion collisions. These attempts follow the classical theoretical work of Popov and Zeldovich, and Greiner and their schools. We then turn to astrophysics. We first review the basic work on the energetics and electrodynamical properties of an electromagnetic black hole and the application of the Schwinger formula around Kerr-Newman black holes as pioneered by Damour and Ruffini. We only focus on black hole masses larger than the critical mass of neutron stars, for convenience assumed to coincide with the Rhoades and Ruffini upper limit of $3.2M_\odot$. In this case the electron Compton wavelength is much smaller than the spacetime curvature and all previous results invariantly expressed can be applied following well established rules of the equivalence principle. We derive the corresponding rate of electron-positron pair production and the introduction of the concept of Dyadosphere. We review recent progress in describing the evolution of optically thick electron-positron plasma in presence of supercritical electric field, which is relevant both in astrophysics as well as ongoing laser beam experiments. In particular we review recent progress based on the Vlasov-Boltzmann-Maxwell equations to study the feedback of the created electron-positron pairs on the original constant electric field. We evidence the existence of plasma oscillations and its interaction with photons leading to energy and number equipartition of photons, electrons and positrons. We finally review the recent progress obtained by using the Boltzmann equations to study the evolution of an electron-positron-photon plasma towards thermal equilibrium and determination of its characteristic timescales. The crucial difference introduced by the correct evaluation of the role of two and three body collisions, direct and inverse, is especially evidenced. We then present some general conclusions. The results reviewed in this report are going to be submitted to decisive tests in the forthcoming years both in physics and astrophysics. To mention only a few of the fundamental steps in testing in physics we recall the starting of experimental facilities at the National Ignition Facility at the Lawrence Livermore National Laboratory as well as corresponding French Laser the Mega Joule project. In astrophysics these results will be tested in galactic and extragalactic black holes observed in binary X-ray sources, active galactic nuclei, microquasars and in the process of gravitational collapse to a neutron star and also of two neutron stars to a black hole giving origin to GRBs. The astrophysical description of the stellar precursors and the initial physical conditions leading to a gravitational collapse process will be the subject of a forthcoming report. As of today no theoretical description has yet been found to explain either the emission of the remnant for supernova or the formation of a charged black hole for GRBs. Important current progress toward the understanding of such phenomena as well as of the electrodynamical structure of neutron stars, the supernova explosion and the theories of GRBs will be discussed in the above mentioned forthcoming report. What is important to recall at this stage is only that both the supernovae and GRBs processes are among the most energetic and transient phenomena ever observed in the Universe: a supernova can reach energy of ˜10^{54} ergs on a time scale of a few months and GRBs can have emission of up to ˜10^{54} ergs in a time scale as short as of a few seconds. The central role of neutron stars in the description of supernovae, as well as of black holes and the electron-positron plasma, in the description of GRBs, pioneered by one of us (RR) in 1975, are widely recognized. Only the theoretical basis to address these topics are discussed in the present report.

42. A. G. Aksenov, R. Ruffini, and G. V. Vereshchagin, "Kinetics of the Mildly Relativistic Plasma and GRBs" in the Proceedings of "The Sun, the stars, the Universe and General Relativity" meeting in honor of 95th Anniversary of Ya. B. Zeldovich in Minsk, AIP Conference Proceedings 1205 (2010) 11-16.

    We consider optically thick photon-pair-proton plasma in the framework of Boltzmann equations. For the sake of simplicity we consider the uniform and isotropic plasma. It has been shown that arbitrary initial distribution functions evolve to the thermal equilibrium state through so called kinetic equilibrium state with common temperature of all particles and nonzero chemical potentials. For the plasma temperature $0.1 - 10$ MeV relevant for GRB (Gamma-Ray Burst) sources we evaluate the thermalization time scale as function of total energy density and baryonic loading parameter.

43. E. Menegoni, S. Pandolfi, S. Galli, M. Lattanzi, A. Melchiorri "Constraints on the dark energy equation of state in presence of a varying fine structure constant" in Int. J. Mod. Phys D19, 507 (2010).

    We discuss the cosmological constraints on the dark energy equation of state in the pres- ence of primordial variations in the fine structure constant. We find that the constraints from CMB data alone on w and the Hubble constant are much weaker when variations in the fine structure constant are permitted. Vice versa, constraints on the fine struc- ture constant are relaxed by more than 50% when dark energy models different from a cosmological constant are considered.

44. C.J.A.P. Martins, E. Menegoni, S. Galli and A. Melchiorri, "Varying couplings in the early universe: correlated variations of α and G, Physical Review D 82 023532 (2010)

    The cosmic microwave background anisotropies provide a unique opportunity to constrain simultaneous variations of the fine-structure constant α and Newton's gravitational constant G. Those correlated variations are possible in a wide class of theoretical models. In this brief paper we show that the current data, assuming that particle masses are constant, give no clear indication for such variations, but already prefer that any relative variations in α should be of the same sign of those of G for variations of 1%. We also show that a cosmic complementarity is present with big bang nucleosynthesis and that a combination of current CMB and big bang nucleosynthesis data strongly constraints simultaneous variations in α and G. We finally discuss the future bounds achievable by the Planck satellite mission.

45. E. Menegoni, "New Constraints on Variations of Fine Structure Constant from Cosmic Microwave Background Anisotropies", GRAVITATIONAL PHYSICS: TESTING GRAVITY FROM SUBMILLIMETER TO COSMIC: Proceedings of the VIII Mexican School on Gravitation and Mathematical Physics. AIP Conference Proceedings, Volume 1256, pp. 288-292 (2010).

    The recent measurements of Cosmic Microwave Background temperature and polarization anisotropy made by the ACBAR, QUAD and BICEP experiments substantially improve the cosmological constraints on possible variations of the fine structure constant in the early universe. In this work I analyze this recent data obtaining the constraint $\alpha/\alpha 0$ = 0.987+/-0.012 at 68% c.l.. The inclusion of the new HST constraints on the Hubble constant further increases the bound to $\alpha/\alpha 0$ = 1.001+/-0.007 at 68% c.l., bringing possible deviations from the current value below the 1% level.

46. A. Melchiorri, F. De Bernardis, E. Menegoni, "Limits on the neutrino mass from cosmology". GRAVITATIONAL PHYSICS: TESTING GRAVITY FROM SUBMILLIMETER TO COSMIC: Proceedings of the VIII Mexican School on Gravitation and Mathematical Physics. AIP Conference Proceedings, Volume 1256, pp. 96-106 (2010).

    We use measurements of luminosity-dependent galaxy bias at several different redshifts, SDSS at z = 0.05, DEEP2 at z = 1 and LBGs at z = 3.8, combined with WMAP five-year cosmic microwave background anisotropy data and SDSS Red Luminous Galaxy survey three-dimensional clustering power spectrum to put constraints on cosmological parameters.

47. A.G. Aksenov, R. Ruffini and G.V. Vereshchagin, "Thermalization of the mildly relativistic plasma", Physical Review D, Vol. 79 (2009) 043008.

    In the recent Letter [1] we considered the approach of nonequilibrium pair plasma towards thermal equilibrium state adopting a kinetic treatment and solving numerically the relativistic Boltzmann equations. It was shown that plasma in the energy range 0.1-10 MeV first reaches kinetic equilibrium, on a timescale $t_{\mathrm{k}} \lesssim 10^{-14}$ sec, with detailed balance between binary interactions such as Compton, Bhabha and Møller scattering, and pair production and annihilation. Later the electron-positron-photon plasma approaches thermal equilibrium on a timescale $t_{\mathrm{th}} \lesssim 10^{-12}$ sec, with detailed balance for all direct and inverse reactions. In the present paper we systematically present details of the computational scheme used in [1], as well as generalize our treatment, considering proton loading of the pair plasma. When proton loading is large, protons thermalize first by proton-proton scattering, and then with the electron-positron-photon plasma by proton-electron scattering. In the opposite case of small proton loading proton-electron scattering dominates over proton-proton one. Thus in all cases the plasma, even with proton admixture, reaches thermal equilibrium configuration on a timescale $t_{\mathrm{th}} \lesssim 10^{-11}$ sec. We show that it is crucial to account for not only binary but also triple direct and inverse interactions between electrons, positrons, photons and protons. Several explicit examples are given and the corresponding timescales for reaching kinetic and thermal equilibria are determined.

48. A. G. Aksenov, R. Ruffini, and G. V. Vereshchagin, "Thermalization of pair plasma with proton loading" in the Proceedings of "PROBING STELLAR POPULATIONS OUT TO THE DISTANT UNIVERSE" meeting, AIP Conference Proceedings 1111 (2009) 344-350.

    We study kinetic evolution of nonequilibrium optically thick electron-positron plasma towards thermal equilibrium solving numerically relativistic Boltzmann equations with energy per particle ranging from 0.1 to 10 MeV. We generalize our results presented in [1], considering proton loading of the pair plasma. Proton loading introduces new characteristic timescales essentially due to proton-proton and proton-electron Coulomb collisions. Taking into account not only binary but also triple direct and inverse interactions between electrons, positrons, photons and protons we show that thermal equilibrium is reached on a timescale $t_{\rm th} \simeq 10^{-11}$ sec.

49. A.G. Aksenov, R. Ruffini and G.V. Vereshchagin, "Thermalization of nonequilibrium electron-positron-photon plasmas", Physical Review Letters, Vol. 99 (2007) No 12, 125003.

    Starting from a nonequilibrium configuration we analyze the role of the direct and the inverse binary and triple interactions in reaching thermal equilibrium in a homogeneous isotropic pair plasma. We focus on energies in the range $0.1-10$ MeV. We numerically integrate the relativistic Boltzmann equation with the exact QED collisional integrals taking into account all binary and triple interactions. We show that first, when a detailed balance is reached for all binary interactions on a time scale $t_k < 10^{-14}$ sec, photons and electron-positron pairs establish kinetic equilibrium. Subsequently, when triple interactions satisfy the detailed balance on a time scale $t_{eq} < 10^{-12}$ sec, the plasma reaches thermal equilibrium. It is shown that neglecting the inverse triple interactions prevents reaching thermal equilibrium. Our results obtained in the theoretical physics domain also find application in astrophysics and cosmology.

50. C.L. Bianco, R. Ruffini, G.V. Vereshchagin and S.-S. Xue, "Equations of Motion and Initial and Boundary Conditions for Gamma-ray Burst", Journal of the Korean Physical Society, Vol. 49 (2006) No. 2, pp. 722-731.

    We compare and contrast the different approaches to the optically thick adiabatic phase of GRB all the way to the transparency. Special attention is given to the role of the rate equation to be self consistently solved with the relativistic hydrodynamic equations. The works of Shemi and Piran (1990), Piran, Shemi and Narayan (1993), Meszaros, Laguna and Rees (1993) and Ruffini, Salmonson, Wilson and Xue (1999,2000) are compared and contrasted. The role of the baryonic loading in these three treatments is pointed out. Constraints on initial conditions for the fireball produced by electro-magnetic black hole are obtained.

51. P. Singh, K. Vandersloot and G.V. Vereshchagin, "Nonsingular bouncing universes in loop quantum cosmology", Physical Review D, Vol. 74 (2006) 043510.

    Nonperturbative quantum geometric effects in loop quantum cosmology (LQC) predict a ρ^2 modification to the Friedmann equation at high energies. The quadratic term is negative definite and can lead to generic bounces when the matter energy density becomes equal to a critical value of the order of the Planck density. The nonsingular bounce is achieved for arbitrary matter without violation of positive energy conditions. By performing a qualitative analysis we explore the nature of the bounce for inflationary and cyclic model potentials. For the former we show that inflationary trajectories are attractors of the dynamics after the bounce implying that inflation can be harmoniously embedded in LQC. For the latter difficulties associated with singularities in cyclic models can be overcome. We show that nonsingular cyclic models can be constructed with a small variation in the original cyclic model potential by making it slightly positive in the regime where scalar field is negative.

52. M. Lattanzi, R. Ruffini and G.V. Vereshchagin, "Joint constraints on the lepton asymmetry of the Universe and neutrino mass from the Wilkinson Microwave Anisotropy Probe", Physical Review D, Vol. 72 (2005) 063003.

    We use the Wilkinson Microwave Anisotropy Probe (WMAP) data on the spectrum of cosmic microwave background anisotropies to put constraints on the present amount of lepton asymmetry L, parametrized by the dimensionless chemical potential (also called degeneracy parameter) xi and on the effective number of relativistic particle species. We assume a flat cosmological model with three thermally distributed neutrino species having all the same mass and chemical potential, plus an additional amount of effectively massless exotic particle species. The extra energy density associated to these species is parametrized through an effective number of additional species ${\Delta N_{others}}^{eff}$.

We find that $0 < |\xi| < 1.1$ and correspondingly $0 < |L| < 0.9$ at 2σ, so that WMAP data alone cannot firmly rule out scenarios with a large lepton number; moreover, a small preference for this kind of scenarios is actually found. We also discuss the effect of the asymmetry on the estimation of other parameters and, in particular, of the neutrino mass. In the case of perfect lepton symmetry, we obtain the standard results. When the amount of asymmetry is left free, we find at 2sigma. Finally we study how the determination of $|L|$ is affected by the assumptions on ΔN^{eff}_{others}. We find that lower values of the extra energy density allow for larger values of the lepton asymmetry, effectively ruling out, at 2sigma level, lepton symmetric models with $\Delta N^{eff}_{others} \simeq 0$.

53. G.V. Vereshchagin, "Gauge Theories of Gravity with the Scalar Field in Cosmology", in "Frontiers in Field Theory", edited by O. Kovras, Nova Science Publishers, New York, (2005), pp. 213-255 (ISBN: 1-59454-127-2).

Brief introduction into gauge theories of gravity is presented. The most general gravitational lagrangian including quadratic on curvature, torsion and nonmetricity invariants for metric-affine gravity is given. Cosmological implications of gauge gravity are considered. The problem of cosmological singularity is discussed within the framework of general relativity as well as gauge theories of gravity. We consider the role of scalar field in connection to this problem. Initial conditions for nonsingular homogeneous isotropic Universe filled by single scalar field are discussed within the framework of gauge theories of gravity. Homogeneous isotropic cosmological models including ultrarelativistic matter and scalar field with gravitational coupling are investigated. We consider different symmetry states of effective potential of the scalar field, in particular restored symmetry at high temperatures and broken symmetry. Obtained bouncing solutions can be divided in two groups, namely nonsingular inflationary and
oscillating solutions. It is shown that inflationary solutions exist for quite general initial conditions like in the case of general relativity. However, the phase space of the dynamical system, corresponding to the cosmological equations is bounded. Violation of the uniqueness of solutions on the boundaries of the phase space takes place. As a result, it is impossible to define either the past or the future for a given solution. However, definitely there are singular solutions and therefore the problem of cosmological singularity cannot be solved in models with the scalar field within gauge theories of gravity.

54. R. Ruffini, M. G. Bernardini, C. L. Bianco, L. Caito, P. Chardonnet, M. G. Dainotti, F. Fraschetti, R. Guida, M. Rotondo, G. Vereshchagin, L. Vitagliano, S.-S. Xue,
"The Blackholic energy and the canonical Gamma-Ray Burst" in Cosmology and Gravitation: XIIth Brazilian School of Cosmology and Gravitation, edited by M. Novello and S.E. Perez Bergliaffa, AIP Conference Proceedings, Vol. 910, Melville, New York, 2007, pp. 55-217.

Gamma-Ray Bursts (GRBs) represent very likely "the" most extensive computational, theoretical and observational effort ever carried out successfully in physics and astrophysics. The extensive campaign of observation from space based X-ray and γ-ray observatory, such as the Vela, CGRO, BeppoSAX, HETE-II, INTEGRAL, Swift, R-XTE, Chandra, XMM satellites, have been matched by complementary observations in the radio wavelength (e.g. by the VLA) and in the optical band (e.g. by VLT, Keck, ROSAT). The net result is unprecedented accuracy in the received data allowing the determination of the energetics, the time variability and the spectral properties of these GRB sources. The very fortunate situation occurs that these data can be confronted with a mature theoretical development. Theoretical interpretation of the above data allows progress in three different frontiers of knowledge: a) the ultrarelativistic regimes of a macroscopic source moving at Lorentz gamma factors up to ~ 400; b) the occurrence of vacuum polarization process verifying some of the yet untested regimes of ultrarelativistic quantum field theories; and c) the first evidence for extracting, during the process of gravitational collapse leading to the formation of a black hole, amounts of energies up to 10^{55} ergs of blackholic energy — a new form of energy in physics and astrophysics. We outline how this progress leads to the confirmation of three interpretation paradigms for GRBs proposed in July 2001. Thanks mainly to the observations by Swift and the optical observations by VLT, the outcome of this analysis points to the existence of a "canonical" GRB, originating from a variety of different initial astrophysical scenarios. The communality of these GRBs appears to be that they all are emitted in the process of formation of a black hole with a negligible value of its angular momentum. The following sequence of events appears to be canonical: the vacuum polarization process in the dyadosphere with the creation of the optically thick self accelerating electron-positron plasma; the engulfment of baryonic mass during the plasma expansion; adiabatic expansion of the optically thick "fireshell" of electron-positron-baryon plasma up to the transparency; the interaction of the accelerated baryonic matter with the interstellar medium (ISM). This leads to the canonical GRB composed of a proper GRB (P-GRB), emitted at the moment of transparency, followed by an extended afterglow. The sole parameters in this scenario are the total energy of the dyadosphere E_{dya}, the fireshell baryon loading M_B defined by the dimensionless parameter $B = M_B c^2 / E_{dya}$, and the ISM filamentary distribution around the source. In the limit $B \longrightarrow 0$ the total energy is radiated in the P-GRB with a vanishing contribution in the afterglow. In this limit, the canonical GRBs explain as well the short GRBs. In these lecture notes we systematically outline the main results of our model comparing and contrasting them with the ones in the current literature. In both cases, we have limited ourselves to review already published results in refereed publications. We emphasize as well the role of GRBs in testing yet unexplored grounds in the foundations of general relativity and relativistic field theories.

55. M. Lattanzi, R. Ruffini and G.V. Vereshchagin, "Do WMAP data constraint the lepton asymmetry of the Universe to be zero?" in Albert Einstein Century International Conference, edited by J.-M. Alimi, and A. Füzfa, AIP Conference Proceedings, Vol. 861, Melville, New York, 2006, pp.912-919.

    It is shown that extended flat ΛCDM models with massive neutrinos, a sizeable lepton asymmetry and an additional contribution to the radiation content of the Universe, are not excluded by the Wilkinson Microwave Anisotropy Probe (WMAP) first year data. We assume a flat cosmological model with three thermally distributed neutrino species having all the same mass and chemical potential, plus an additional amount of effectively massless exotic particle species X. After maximizing over seven other cosmological parameters, we derive from WMAP first year data the following constraints for the lepton asymmetry L of the Universe (95% CL): $0 < |L| < 0.9$, so that WMAP data alone cannot firmly rule out scenarios with a large lepton number; moreover, a small preference for this kind of scenarios is actually found. We also find for the neutrino mass $m_\nu < 1.2eV$ and for the effective number of relativistic particle species $-0.45 < \Delta N^{eff} < 2.10$, both at 95% CL. The limit on ΔN^{eff} is more restrictive man others found in the literature, but we argue that this is due to our choice of priors.

56. R. Ruffini, C.L. Bianco, G.V. Vereshchagin, S.-S. Xue "Baryonic loading and e^+e^- rate equation in GRB sources" to appear in the proceedings

of "Relativistic Astrophysics and Cosmology - Einstein's Legacy" Meeting, November 7-11, 2005, Munich, Germany.

The expansion of the electron-positron plasma in the GRB phenomenon is compared and contrasted in the treatments of Meszaros, Laguna and Rees, of Shemi, Piran and Narayan, and of Ruffini et al. The role of the correct numerical integration of the hydrodynamical equations, as well as of the rate equation for the electron-positron plasma loaded with a baryonic mass, are outlined and confronted for crucial differences.

57. G.V. Vereshchagin, M. Lattanzi, H.W. Lee, R. Ruffini, "Cosmological massive neutrinos with nonzero chemical potential: I. Perturbations in cosmological models with neutrino in ideal fluid approximation", in proceedings of the Xth Marcel Grossmann Meeting on Recent Developments in Theoretical and Experimental General Relativity, World Scientific: Singapore, 2005, vol. 2, pp. 1246-1248.

    Recent constraints on neutrino mass and chemical potential are discussed with application to large scale structure formation. Power spectra in cosmological model with hot and cold dark matter, baryons and cosmological term are calculated in newtonian approximation using linear perturbation theory. All components are considered to be ideal fluids. Dissipative processes are taken into account by initial spectrum of perturbations so the problem is reduced to a simple system of equations. Our results are in good agreement with those obtained before using more complicated treatments.

58. M. Lattanzi, H.W. Lee, R. Ruffini, G.V. Vereshchagin, "Cosmological massive neutrinos with nonzero chemical potential: II. Effect on the estimation of cosmological parameters", in proceedings of the Xth Marcel Grossmann Meeting on Recent Developments in Theoretical and Experimental General Relativity, World Scientific: Singapore, 2005, vol. 2, pp. 1255-1257.

    The recent analysis of the cosmic microwave background data carried out by the WMAP team seems to show that the sum of the neutrino mass is <0.7 eV. However, this result is not model-independent, depending on precise assumptions on the cosmological model. We study how this result is modified when the assumption of perfect lepton symmetry is dropped out.

59. R. Ruffini, M. Lattanzi and G. Vereshchagin, "On the possible role of massive neutrinos in cosmological structure formation" in Cosmology

and Gravitation: Xth Brazilian School of Cosmology and Gravitation, edited by M. Novello and S.E. Perez Bergliaffa, AIP Conference Proceedings, Vol. 668, Melville, New York, 2003, pp.263-287.

In addition to the problem of galaxy formation, one of the greatest open questions of cosmology is represented by the existence of an asymmetry between matter and antimatter in the baryonic component of the Universe. We believe that a net lepton number for the three neutrino species can be used to understand this asymmetry. This also implies an asymmetry in the matter-antimatter component of the leptons. The existence of a nonnull lepton number for the neutrinos can easily explain a cosmological abundance of neutrinos consistent with the one needed to explain both the rotation curves of galaxies and the flatness of the Universe. Some propedeutic results are presented in order to attack this problem.

60. A.G. Aksenov, C.L. Bianco, R. Ruffini and G.V. Vereshchagin, "GRBs and the thermalization process of electron-positron plasmas" in the Proceedings of the "Gamma Ray Bursts 2007" meeting, AIP Conf.Proc. 1000 (2008) 309-312.

    We discuss temporal evolution of the pair plasma, created in Gamma-Ray Bursts sources. A particular attention is paid to the relaxation of plasma into thermal equilibrium. We also discuss the connection between the dynamics of expansion and spatial geometry of plasma. The role of the baryonic loading parameter is emphasized.

61. A. G. Aksenov, R. Ruffini, and G. V. Vereshchagin, "Thermalization of Electron-Positron-Photon Plasmas with an Application to GRB" in RELATIVISTIC ASTROPHYSICS: 4th Italian-Sino Workshop, AIP Conference Proceedings, Vol. 966, Melville, New York, 2008, pp. 191-196.

    The pair plasma with photon energies in the range $0.1 - 10$MeV is believed to play crucial role in cosmic Gamma-Ray Bursts. Starting from a nonequilibrium configuration we analyze the role of the direct and the inverse binary and triple interactions in reaching thermal equilibrium in a homogeneous isotropic pair plasma.We numerically integrate the relativistic Boltzmann equation with the exact QED collisional integrals taking into account all binary and triple interactions. We show that first, when a detailed balance is reached for all binary interactions on a time scale $t_k = 10^{-14}$sec , photons and electronpositron pairs establish kinetic equilibrium. Subsequently, when triple interactions satisfy the detailed balance on a time scale $t_{eq} = 10^{-12}$sec , the plasma reaches thermal equilibrium. It is shown that neglecting the inverse triple interactions prevents reaching thermal equilibrium. Our results obtained in the theoretical physics domain also find application in astrophysics and cosmology.

62. R. Ruffini, G. V. Vereshchagin and S.-S. Xue, "Vacuum Polarization and Electron-Positron Plasma Oscillations" in RELATIVISTIC ASTROPHYSICS: 4th Italian-Sino Workshop, AIP Conference Proceedings, Vol. 966, Melville, New York, 2008, pp. 207-212.

    We study plasma oscillations of electrons-positron pairs created by the vacuum polarization in an uniform electric field. Our treatment, encompassing the case of $E > E_c$, shows also in the case $E < E_c$the existence of a maximum Lorentz factor acquired by electrons and positrons and allows determination of the a maximal length of oscillation. We quantitatively estimate how plasma oscillations reduce the rate of pair creation and increase the time scale of the pair production.

4.3 Invited talks at international conferences

1. "Cosmic horizon for GeV sources and photonphoton scattering", First ICRANet-Minsk workshop on high energy astrophysics, National Academy of Sciences of Belarus, Minsk, Belarus, April 26-28, 2017.

    (G.V. Vereshchagin)

2. "Cosmic horizon for GeV sources and photonphoton scattering", XIII International Conference on Gravitation, Astrophysics and Cosmology and 15th Italian-Korean Symposium on Relativistic Astrophysics: A joint meeting, Ewha Womans University, Seoul, Korea, July 3 - 7, 2017.

    (G.V. Vereshchagin)

3. "Cosmic absorption of high energy particles", Supernovae, Hypernovae, and Binary Driven Hypernovae, An Adriatic Workshop, Pescara - June 20-30, 2016.

    (G.V. Vereshchagin)

4. "Thermal emission in the early afterglow", 1st Scientific ICRANet Meeting in Armenia, Yerevan, Armenia, 30 June - 4 July 2014.

    (G.V. Vereshchagin)

5. “Photospheric emission from relativistic outflows”, Zeldovich-100 International Conference, Space Research Institute (IKI), Moscow, Russia, 16-20 June, 2014

   (G.V. Vereshchagin)

6. “Dark matter massive fermions and Einasto profiles in galactic haloes “

   (Ivan Siutsou)

   Subatomic particles, Nucleons, Atoms, Universe: Processes and Structure International conference in honor of Ya. B. Zeldovich 100th Anniversary, March 10-14, 2014, Minsk, Belarus

7. “DM halos and super massive dark objects at sub-parsec scales:the nature of the DM particle “

   (Carlos R. Argüelles)

   Subatomic particles, Nucleons, Atoms, Universe: Processes and Structure International conference in honor of Ya. B. Zeldovich 100th Anniversary, March 10-14, 2014, Minsk, Belarus

8. “Physics of non-dissipative ultrarelativistic photospheres“

   (G.V. Vereshchagin)

   On recent developments in theoretical and experimental general relativity, gravitation and relativistic field theories: XIII Marcel Grossmann Meeting, Stockholm, 1-7 July 2012.

9. ”Photon thick and photon thin relativistic outflows and GRBs”

   (I.A. Siutsou, R. Ruffini and G.V. Vereshchagin)

   On recent developments in theoretical and experimental general relativity, gravitation and relativistic field theories: XIII Marcel Grossmann Meeting, Stockholm, 1-7 July 2012.

10. ”Monte Carlo simulations of the photospheric emission in GRBs”

    (D. Begue, I.A. Siutsou and G.V. Vereshchagin)

    On recent developments in theoretical and experimental general relativity, gravitation and relativistic field theories: XIII Marcel Grossmann Meeting, Stockholm, 1-7 July 2012.

11. ”Phase space evolution of pairs created in strong electric fields” (A. Benedetti, R. Ruffini and G.V. Vereshchagin) On recent developments in theoretical and experimental general relativity, gravitation and relativistic field theories: XIII Marcel Grossmann Meeting, Stockholm, 1-7 July 2012.

12. ”Applications of the Boltzmann equation: from an interacting plasma toward the photospheric emission of a GRB” (A. Benedetti, R. Ruffini and G.V. Vereshchagin) Erasmus Mundus School, Nice, France, 3rd – 19th September, 2012.

13. ”Photospheric emission from thermally accelerated relativistic outflows”

    GRBs, their progenitors and the role of thermal emission, Les Houches, France, 2-7 October, 2011

    (G.V. Vereshchagin, R. Ruffini and I.A. Siutsou)

14. “Thermalization of the pair plasma”

    (G.V. Vereshchagin, A.G. Aksenov and R. Ruffini)

    From Nuclei to White Dwarfs and Neutron Stars, Les Houches, France, 3-8 April, 2011

15. ”Photospheric emission from relativistic outflows: 1DHD”

    (G.V. Vereshchagin, R. Ruffini and I.A. Siutsou)

    Recent News from the MeV, GeV and TeV Gamma-Ray Domains, Pescara, Italy, 21-26 March, 2011

16. ”Thermalization of degenerate electron-positron plasma”

    I.A. Siutsou, A.G. Aksenov, R. Ruffini and G.V. Vereshchagin

    IRAP Ph.D. Erasmus Mundus School—May 27, 2011, Nice, France

17. ”Semidegenerate self-gravitating systems of fermions as central objects and dark matter halos in galaxies”

    (I. A. Siutsou, A. Geralico and R. Ruffini)

    Recent News from the MeV, GeV and TeV Gamma-Ray Domains, March 24, 2011, Pescara, Italy

18. ”Thermalization of degenerate electron-positron plasma”

    (I.A. Siutsou, A.G. Aksenov, G.V. Vereshchagin and R. Ruffini)

    3rd Galileo-Xu Guangqi Meeting—October 12, 2011, Beijing, China

19. ”Photospheric emission of relativistically expanding outflows”

    (I.A. Siutsou, G.V. Vereshchagin and R. Ruffini)

    12th Italian-Korean Symposium on Relativistic Astrophysics—July 5, 2011, Pescara, Italy

20. On the frequency of oscillations in the pair plasma generated by a strong electric field.

    (Alberto Benedetti, W.-B. Han, R. Ruffini, G.V. Vereshchagin)
    IRAP Ph.D. Erasmus Mundus Workshop, April 5, 2011, Pescara (Italy)

21. Oscillations in the pair plasma generated by a strong electric field

    (Alberto Benedetti, W.-B. Han, R. Ruffini, G.V. Vereshchagin)
    Italian-Korean Meeting, July 4-9, 2011, Pescara (Italy)

22. Electron-Positron plasma oscillations: hydro-electrodynamic and kinetic approaches

    (Alberto Benedetti, R. Ruffini, G.V. Vereshchagin)
    IRAP Ph.D. Erasmus Mundus School, September 7, 2011, Nice (France)

23. Boltzmann equation: from an interacting plasma toward the photospheric emission of a GRB

    (Alberto Benedetti, A. Aksenov, R. Ruffini, I. Siotsou, G.V. Vereshchagin)
    IRAP Ph.D. Erasmus Mundus Workshop, October 6, 2011, Les Houches (France)

24. Electron-Positron plasma oscillations: hydro-electrodynamic and kinetic approaches.

    (Alberto Benedetti, A. Aksenov, R. Ruffini, I. Siutsou, G.V. Vereshchagin)
    Galileo-Xu Guanqui Meeting, October 12, 2011, Beijing (China)

25. “Inflation in a general reionization scenario ”

    (S. Pandolfi)

    Essential Cosmology for the Next Generation, Puerto Vallarta, Mexico, January 10-14, 2011

26. “Constraints on Inflation in extended cosmological scenarios ”

    (S. Pandolfi)

    28 January 2011, Dark Cosmlogy Center, Copenhagen, Denmark.

27. “Theoretical Development toward the Planck mission ”

    (S. Pandolfi)

    IRAP PhD and Erasmus MundusWorkshop: Workshop on Recent News from the GeV and TeV Gamma-Ray Domains: Results and Interpretations,21-26 March 2011, ICRANet (Pescara), Italy.

28. “Joint Astrophysical and Cosmological constrains on reionization ”

    (S. Pandolfi)

    DAVID WORKSHOP VI, Scuola Normale Superiore, Pisa, October 18-20 2011

29. “New constraints on features in the primordial spectrum ”

    (M. Benetti)

    3rd Galileo- Xu Guangqi meeting, Beijing (China), October 11-15, 2011.

30. “Thermalization of the pair plasma”

    (G.V. Vereshchagin with A.G. Aksenov and R. Ruffini)

    Korean Physical Society 2010 Fall Meeting, Pyeong-chang, Korea, 20-22 October, 2010.

31. “The spatial structure of expanding optically thick relativistic plasma and the onset of GRBs”

    (G.V. Vereshchagin with A.G. Aksenov, G. de Barros and R. Ruffini)

    GRB 2010 / Dall’eV al TeV tutti i colori dei GRB, Secondo Congresso Italiano sui Gamma-ray Burst, Cefalu’ 15-18 June 2010.

32. "From thermalization mechanisms to emission processes in GRBs"

    (G.V. Vereshchagin)

    XII Marcel Grossmann Meeting, Paris, 12-18 July 2009.

33. "Kinetics of the mildly relativistic plasma and GRBs"

    (A.G. Aksenov R. Ruffini, and G.V. Vereshchagin)

    "The Sun, the Stars, the Universe, and General Relativity" - International conference in honor of Ya. B. Zeldovich 95th Anniversary, Minsk, Belarus, April 19-23, 2009.

34. "Pair plasma around compact astrophysical sources: kinetics, electrodynamics and hydrodynamics"

    (G.V. Vereshchagin and R. Ruffini)

    Invited seminar at RMKI, Budapest, February 24, 2009.

35. "Thermalization of the pair plasma with proton loading"

    (G.V. Vereshchagin, R. Ruffini, and A.G. Aksenov)

    Probing Stellar Populations out to the Distant Universe, Cefalu', Italy, September 7-19, 2008.

36. "Thermalization of the pair plasma with proton loading"

    (G.V. Vereshchagin, R. Ruffini, and A.G. Aksenov)

    3rd Stueckelberg Workshop, Pescara, Italy, 8-18 July, 2008.

37. "Thermalization of the pair plasma"

    (G.V. Vereshchagin, R. Ruffini, and A.G. Aksenov)

38. "Non-singular solutions in Loop Quantum Cosmology"

    (G.V. Vereshchagin)

    2nd Stueckelberg Workshop, Pescara, Italy, 3-7 September, 2007.

39. "(From) massive neutrinos and inos and the upper cutoff to the fractal structure of the Universe (to recent progress in theoretical cosmology)"

    (G.V. Vereshchagin, M. Lattanzi and R. Ruffini)

    A Century of Cosmology, San Servolo, Venice, Italy, 27-31 August, 2007.

40. “Pair creation and plasma oscillations”

    (G.V. Vereshchagin, R. Ruffini, and S.-S. Xue)
    4th Italian-Sino Workshop on Relativistic Astrophysics, Pescara, Italy, 20-29 July, 2007.

41. “Thermalization of electron-positron plasma in GRB sources”

    (G.V. Vereshchagin, R. Ruffini, and A.G. Aksenov)
    Xth Italian-Korean Symposium on Relativistic Astrophysics, Pescara, Italy, 25-30 June, 2007.

42. “Kinetics and hydrodynamics of the pair plasma”

    (G.V. Vereshchagin, R. Ruffini, C.L. Bianco, A.G. Aksenov)

43. “Pair creation and plasma oscillations”

    (G.V. Vereshchagin, R. Ruffini and S.-S. Xue)
    Cesare Lattes Meeting on GRBs, Black Holes and Supernovae, Mangaratiba-Portobello, Brazil, 26 February - 3 March 2007.

44. “Cavallo-Rees classification revisited”

    (G.V. Vereshchagin, R.Ruffini and S.-S. Xue)

    On recent developments in theoretical and experimental general relativity, gravitation and relativistic field theories: XIth Marcel Grossmann Meeting, Berlin, Germany, 23-29 July, 2006.

45. “Kinetic and thermal equilibria in the pair plasma”

    (G.V. Vereshchagin)

    The 1st Bego scientific rencontre, Nice, 5-16 February 2006.

46. “From semi-classical LQC to Friedmann Universe”

    (G.V. Vereshchagin)

    Loops ’05, Potsdam, Golm, Max-Plank Institut für Gravitationsphysik (Albert-Einstein-Institut), 10-14 October 2005.

47. “Equations of motion, initial and boundary conditions for GRBs”

    (G.V. Vereshchagin, R. Ruffini and S.-S. Xue)

    IXth Italian-Korean Symposium on Relativistic Astrophysics, Seoul, Mt. Kumgang, Korea, 19-24 July 2005.

48. "On the Cavallo-Rees classification and GRBs"

    (G.V. Vereshchagin, R. Ruffini and S.-S. Xue)

    II Italian-Sino Workshop on Relativistic Astrophysics, Pescara, Italy, 10-20 June, 2005.

49. "New constraints on features in the primordial spectrum "

    (M. Benetti)

    Essential Cosmology for the Next Generation Ph.D School, January 16-21 2012, Cancun, Mexico

50. "New constraints on features in the primordial spectrum "

    (M. Benetti)

    XIth School of Cosmology, Gravitational Lenses: their impact in the study of galaxies and Cosmology, Ph.D School, September 17-22 2012, Cargese, France

51. "New Horizons for Observational Cosmology "

    (M. Benetti)

    Ph.D School, June 30th-July 6th 2013, Varenna, Italy

52. "BLACK HOLES IN GAMMA RAY-BURSTS AND GALACTIC NUCLEI "

    (R. Ruffini, C.R. Arguelles, B.M.O. Fraga, A. Geralico, H. Quevedo and J.A. Rueda, and I. Siutsou)

    3rd Galileo–Xuguangqi Meeting, Beijing, China, 11–15 October 2011

4.4 Lecture courses

1. "Relativistic kinetic theory and its applications in astrophysics and cosmology", 4 lectures

   (G.V. Vereshchagin)

   IRAP Ph.D. Erasmus Mundus September school, Nice, 2 – 20 September, 2013.

2. “Relativistic Boltzmann equations”, 2 lectures

   (G.V. Vereshchagin)

   Second Bego Rencontre, IRAP Ph.D. Erasmus Mundus school, Nice, 16 – 31 May, 2013.

3. “First light from Gamma Ray Bursts”, 3 lectures

   (G.V. Vereshchagin)

   IRAP Ph.D. Erasmus Mundus September school, Nice, 3 – 21 September, 2012.

4. “Relativistic kinetic theory and its applications in astrophysics and cosmology”, 5 lectures

   (G.V. Vereshchagin)

   XV Brazilian School of Cosmology and Gravitation, Mangaratiba - Rio de Janeiro – Brazil, August 19 - September 1, 2012.

5. ”Pair plasma in GRBs and cosmology”

   (G.V. Vereshchagin)

   2 lectures, IRAP Ph.D. Erasmus Mundus September school, 12 – 23 September, 2011, University of Nice Sophia Antipolis, Nice, France.

6. “Relativistic kinetic theory and its applications in astrophysics and cosmology”

   (G.V. Vereshchagin)

   Lecture course for International Relativistic Astrophysics PhD, Erasmus Mundus Joint Doctorate Program from the

   European Commission, September 6-24, 2010, University of Nice Sophia Antipolis, Nice, France.

7. “Relativistic kinetic theory and its applications”, IRAP Ph.D. lectures

   (G.V. Vereshchagin)

   February 1-19, 2010, Observatoire de la Cote d’Azur, Nice, France.

8. Inflationary Constraints and reionization

   (S. Pandolfi)

   IRAP Ph.D. Lectures in Nice, Observatoire de la Cote d'Azur, 12-16 February 2010.

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