

THEORY GROUP

R.Aloisio, Z.Berezhiani, V.Berezinsky, P. Ciarcelluti, M. P. Costantini, G. Di Carlo, A.Galante, L. Gianfagna, A.F.Grillo, F.Mendez, F. Nesti, N. Rossi, A. Sakharov, F.Vissani.

The activity of the group in year 2004 has concerned research in the fields: Astroparticle Physics (mainly in Iniziativa Specifica FA51), Particle Phenomenology (mainly in IS PI21) and Computer simulations of Lattice Gauge Theory (in IS GS11). In addition, a research activity on Planck Scale Kinematics and Phenomenology is continuing, also partly included in year 2004 in IS GS11.

In 2005 a partial rearrangement of IS will take place: IS GS11 ceases activity and the scientific activity on lattice field theory will take place in IS PI12, while a new IS (comprising also Roma1 and SISSA groups), GS51, has been started, devoted to Phenomenology near the Planck Scale.

The activities are more specifically reported below.

1 Astroparticle Physics

The Astroparticle group of LNGS in 2004 included R.Aloisio, V.Berezinsky, M.L.Costantini, F.Vissani and visitors V.Dokuchaev (Institute for Nuclear Research, Moscow), Yu.Eroshenko (Institute for Nuclear Research, Moscow), B.Hnatyk (Lviv University, Ukraine), S.Grigorieva (Institute for Nuclear Research, Moscow) and A.Gazizov (DESY, Germany). The group worked in close collaboration with A.Vilenkin (Tufts University, USA), M.Kachelriess (MPI, Munich), P.Blasi (Arcetri Observatory, Firenze), G.Senjanović (ICTP, Trieste), A.Strumia (Pisa University) and others

Scientific work

The main field of the work is astroparticle physics, including neutrino oscillations, physics in underground detectors, massive neutrinos, ultra high energy cosmic rays, topological defects, and high energy neutrino astrophysics. From several works finished in 2004 two following results can be mentioned

In the work by Aloisio and Berezinsky the diffusive propagation of UHECR in the intergalactic magnetic fields has been systematically studied. The propagation theorem is proved, according to which diffuse spectrum has a universal form independent of the mode of propagation, when distance between sources becomes much smaller than all propagation lengths. The spectra in diffusion approximation are calculated analytically. The paper is published in *Ap.J.* 612 (2004) 900.

In a series of works by Aulakh, Bajc, Melfo, Senjanović and Vissani, fermion masses and in particular neutrino masses in $SO(10)$ are investigated. Interesting indications for type

II seesaw were obtained. In order to exploit the predictions of the minimal supersymmetric SO(10) model, a detailed calculation of the mass spectrum has been performed (Phys.Rev. D70, 035007).

Conferences, seminars and other activities

R.Aloisio works as the scientific secretary of the LNGS scientific committee

V.Berezinsky works as an editor of Int. Journal “Astroparticle Physics”

F.Vissani works (together with C.Cattadori) as the organizer of the LNGS seminar

R.Aloisio presented the invited talks at CRIS-04 conference in Catania,

V.Berezinsky presented the invited lecture at DESY Theory workshop “Particles and Cosmology” in DESY (Germany), a course of lectures at ISAPP 2004 in LNGS, invited talks at the European Conference on Very High Energy Cosmic Rays (Greece), at CRIS-04 (Catania), QUARKS-04 in Moscow and at UHECR symposium at Leeds.

M.L.Costantini gave an invited talk at IFAE 04 in Torino.

F.Vissani was an organizer of ICTP Summer School on Astroparticle Physics in Trieste (with G.Senjanovic et al), and of the Summer Institute at LNGS: Particles Gravity and Cosmology, (with Z.Berezhiani et al). He acted as a convenor of Parallel Session on “Absolute Neutrino Masses” at NOW2004, Otranto (with A.Giuliani). F.Vissani presented an invited talk at ECT* (Trento) for the International Workshop on Fundamental Interactions, and a summary talk for the working group on “Flavors and neutrinos” at the “4th meeting EuroGDR Supersymmetry”, in LNF (Frascati).

Journal and Proceedings publications in 2004

1. R. Aloisio, V. Berezinsky, M. Kachelriess,
FRAGMENTATION FUNCTIONS IN SUSY QCD AND UHECR SPECTRA PRODUCED IN TOP-DOWN MODELS
Phys.Rev. D69 (2004) 094023
2. R. Aloisio, V. Berezinsky,
DIFFUSIVE PROPAGATION OF UHECR AND THE PROPAGATION THEOREM
Astroph. J, 612 (2004) 612.
3. R. Aloisio, P. Blasi, A. V. Olinto,
NEUTRALINO ANNIHILATION AT THE GALACTIC CENTER REVISITED
JCAP 0405 (2004) 007
4. R. Aloisio,
MULTIWAVELENGTH OBSERVATION OF WIMP ANNIHILATION
Proceedings of 10th Marcel Grossman Meeting
5. R. Aloisio, V. Berezinsky, M. Kachelriess,
ULTRA HIGH ENERGY COSMIC RAY SPECTRA IN TOP-DOWN MODELS

CRIS2004

6. V.S.Berezinsky, S.I.Grigorieva, B.I.Hnatyk,
EXTRAGALACTIC UHE PROTON SPECTRUM AND PREDICTION FOR IRON NU-
CLEI FLUX AT $10^8 - 10^9$ GeV *Astropart.Phys.* 21 (2004) 617-625
7. V.Berezinsky, A.Gazizov, S. Grigorieva,
PROPAGATION AND SIGNATURES OF ULTRA HIGH ENERGY COSMIC RAYS
Nucl. Phys B (Proc. Suppl) 136 (2004) 147.
8. V. Berezinsky, V. Dokuchaev, Y. Eroshenko,
COSMOLOGICAL ORIGIN OF SMALL-SCALE CLUMPS AND DM ANNIHILATION
Proceedings of the 6th RESCEU International Symposium on "Frontier in Astroparticle
Physics and Cosmology", eds. K. Sato and S. Nagataki (Universal Academy Press Inc.:
Tokyo, Japan, 2004), p241-248
9. M. L. Costantini, A. Ianni, F. Vissani,
SN1987A AND THE PROPERTIES OF NEUTRINO BURST
Phys.Rev. D70 (2004) 043006
10. F. Cavanna, M. L. Costantini, O. Palamara, F. Vissani,
NEUTRINOS AS ASTROPHYSICAL PROBES
Surveys High Energ.Phys. 19 (2004) 35-54
11. F. Vissani,
NEUTRINOS MASSES AND MIXING: WHAT DO THEY MEAN?
*Eur.Phys.J.C*33 (2004) 857
12. C.Aulakh, B.Bajc, A.Melfo, G.Senjanović, F.Vissani,
THE MINIMAL SUPERSYMMETRIC GRAND UNIFIED THEORY
*Phys.Lett.B*588 (2004) 196
13. B.Bajc, A.Melfo, G.Senjanović, F.Vissani,
THE MINIMAL SUPERSYMMETRIC GRAND UNIFIED THEORY *Phys.Rev.D*70 (2004)
035002
14. B.Bajc, G.Senjanović, F.Vissani,
PROBING THE NATURE OF THE SEESAW IN RENORMALIZABLE SO(10)
*Phys.Rev.D*70 (2004) 093002

Preprints of 2004

1. R.Aloisio, V.Berezinsky,
ANTI-GZK EFFECT IN ULTRA HIGH ENERGY COSMIC RAYS DIFFUSIVE PROP-
AGATION
astro-ph/0412578
2. V.Berezinsky, V.Dokuchaev,
HIGH-ENERGY NEUTRINOS AS OBSERVATIONAL SIGNATURE OF MASSIVE BLACK
HOLE FORMATION

astro-ph/0401310

3. V.Berezinsky, M.Narayan, F.Vissani,
LOW SCALE GRAVITY AS THE SOURCE OF NEUTRINO MASSES?
hep-ph/0401029

4. M.L.Costantini, F.Vissani,
EXPECTED NEUTRINO SIGNAL FROM SUPERNOVA REMNANT RX J1713.7-3946
AND FLAVOR OSCILLATIONS
astro-ph/0411761

5. M.Cirelli, G.Marandella, A.Strumia, F.Vissani,
PROBING OSCILLATIONS INTO STERILE NEUTRINOS WITH COSMOLOGY, AS-
TROPHYSICS AND EXPERIMENTS
astro-ph/0403158

6. APS Neutrino Study [with F.Vissani],
THEORY OF NEUTRINOS
hep-ph/0412099

2 Particle Phenomenology

During this year the activity of the group, which included Z. Berezhiani, P. Ciarcellutti, L. Gianfagna, F. Nesti and A. Sakharov, was mainly devoted to different problems of particle astrophysics and cosmology. The following results can be mentioned.

Z. Berezhiani together with A. Dolgov (INFN Ferrara) suggested the mechanism for the generation of the large scale cosmic magnetic fields. The seeds for the cosmic magnetic could be generated in the primeval plasma slightly before hydrogen recombination. Non-zero vorticity, necessary for that, might be created by the photon diffusion in the second order in the temperature fluctuations or by isocurvature perturbations. The spectrum of resulting seed fields was calculated and it was concluded that a reasonable galactic dynamo is needed to amplify the seed fields by 8-9 orders of magnitude in order to explain the magnitudes of coherent magnetic fields in galaxies.

Z. Berezhiani and P. Ciarcelluti have studied cosmological implications of the mirror world, an identical copy of the observed particle world which interacts with the latter only gravitationally. The mirror baryons, being invisible for ordinary observer, could constitute dark matter of the universe, with specific implications for the large scale structure (LSS) of the Universe and the cosmic microwave background (CMB). It was given a complete numerical calculations by a special computational code for the LSS power spectrum and the CMB angular anisotropies in the cases of dark matter entirely constituted by mirror baryons, and for the case of mixed cold dark matter and mirror dark matter model.

Z. Berezhiani, in collaboration with A. Drago and G. Pagliara (Ferrara), proposed a model to explain the gravitational wave signals observed by EXPLORER and NAUTILUS

detectors during the year 2001. The sudden variations in the composition and structure of an hybrid star can be triggered by its rapid spin-down, induced by r-mode instabilities. The discontinuity of this process is due to the surface tension between hadronic and quark matter and in particular to the overpressure needed to nucleate new structures of quark matter in the mixed phase. The consequent mini-collapses in the star can produce highly energetic gravitational wave bursts.

A. Sakharov with collaborators, J. Ellis (CERN), N.E. Mavromatos (London) and D.V. Nanopoulos (Texas) discussed that possible patterns of violation of the Lorentz invariance and of the equivalence principle due to the interaction of the propagating particle with the foamy space-time fluctuations expected in quantum gravity theories. These violations may not be universal, and different types of energetic particles may violate Lorentz invariance and the equivalence principle by varying amounts. The phenomenological implications of these phenomena were also discussed.

Participation in conferences

Int. Conf. "Frontier Science 2004: Physics and Astrophysics in Space", Monteporzio Catone, Italy, 14-19 June 2004, poster presentation of P. Ciarcelluti "STRUCTURE FORMATION, CMB AND LSS IN MIRROR DARK MATTER SCENARIO"

Gran Sasso Summer Institute on "Particles, Gravity and Cosmology", LNGS, Assergi, Italy, 30 Aug - 10 Sept 2004, talks of P. Ciarcelluti "MIRROR BARYONS AS DARK MATTER", F. Nesti "SO(10) model for fermion masses and mixing" and A. Sakharov "ASTROPHYSICAL PROBES OF QUANTUM GRAVITY"

Int. Workshop on Neutrino Oscillations NOW 2004, Conca Specchiula, Otranto, Italy, 11-17 Sept. 2004, invited talk di F. Nesti "SO(10) MODEL FOR FERMION MASSES AND MIXING"

Int. Workshop on Particle Physics and the Early Universe COSMO'04, Toronto, Canada, 17-21 Sept. 2004, talk di A. Sakharov "ASTROPHYSICAL PROBES OF QUANTUM GRAVITY"

Int. Conf. on "Theoretical Particle Physics and Cosmology", Tbilisi, Georgia, 20-25 Sept. 2004, invited talk di Z. Berezhiani "SUPERSYMMETRIC SO(10) MODEL FOR FERMION MASSES AND MIXING"

DESY Theory Workshop 2004 on Particle Cosmology "Dark Matter, Dark Energy, Early Universe, High Energy Cosmic Rays", DESY, Hamburg, Germany, 28 Sept - 1 Oct 2004, invited talk di A. Sakharov "ASTROPHYSICAL PROBES OF QUANTUM GRAVITY"

Publications

1. Z. Berezhiani, A.D. Dolgov,
GENERATION OF LARGE SCALE MAGNETIC FIELDS AT RECOMBINATION EPOCH
Astropart. Phys. 21, 59-69 (2004)

2. L. Gianfagna, M. Giannotti, F. Nesti,
MIRROR WORLD, SUPERSYMMETRIC AXION AND GAMMA RAY BURSTS,
JHEP 0410, 044 (2004)
3. Z. Berezhiani,
MIRROR WORLD AND ITS COSMOLOGICAL CONSEQUENCES,
Int. J. Mod. Phys. A19, 3775-3806 (2004)
4. Z. Berezhiani, P. Ciarcelluti, D. Comelli, F.L. Villante,
STRUCTURE FORMATION WITH MIRROR DARK MATTER: CMB AND LSS
Int. J. Mod. Phys. D22, 1334-1342 (2004)
5. P. Ciarcelluti,
COSMOLOGY WITH MIRROR DARK MATTER I: LINEAR EVOLUTION OF PER-
TURBATIONS
Sep 2004. 33pp., e-Print Archive: astro-ph/0409629, accepted in Int. J. Mod. Phys. D
6. P. Ciarcelluti,
COSMOLOGY WITH MIRROR DARK MATTER II: COSMIC MICROWAVE BACK-
GROUND AND LARGE SCALE STRUCTURE
Sep 2004. 36pp., e-Print Archive: astro-ph/0409630, accepted in Int. J. Mod. Phys. D
7. P. Ciarcelluti,
STRUCTURE FORMATION, CMB AND LSS IN A MIRROR DARK MATTER SCE-
NARIO
Sep 2004. 8pp. e-Print Archive: astro-ph/0409633, to be published in Frascati Physics
Series, Proc. Int. Conf. "Frontier Science 2004: Physics and Astrophysics in Space",
Monteporzio Catone, Italy, 14-19 June 2004
8. J. Ellis, N.E. Mavromatos, D.V. Nanopoulos, A.S. Sakharov,
SPACE-TIME FOAM MAY VIOLATE THE PRINCIPLE OF EQUIVALENCE
Int. J. Mod. Phys. A19, 4413-4430 (2004)
9. J. Ellis, N.E. Mavromatos, D.V. Nanopoulos, A.S. Sakharov,
SYNCHROTRON RADIATION AND QUANTUM GRAVITY
Nature 428, 386 (2004)
10. J. Ellis, N.E. Mavromatos, D.V. Nanopoulos, A. Sakharov,
BRANY LIOUVILLE INFLATION
New J. Phys. 6, 171 (2004)
- 1.] M.Yu. Khlopov, S.G. Rubin, A.S. Sakharov,
PRIMORDIAL STRUCTURE OF MASSIVE BLACK HOLE CLUSTERS
Jan 2004. 17pp. e-Print Archive: astro-ph/0401532, accepted in Astropart. Phys.
12. E. Sarkisyan, A.S. Sakharov,
ON SIMILARITIES OF BULK OBSERVABLES IN NUCLEAR AND PARTICLE COL-
LISIONS
Oct 2004. 14pp. e-Print Archive: hep-ph/0410324
13. A. Drago, G. Pagliara, Z. Berezhiani,

3 Computer Simulations of Lattice Gauge theories

During year 2004 this activity was pursued by: G. Di Carlo, A. Galante in collaboration with V. Azcoiti and V. Laliena (Zaragoza).

The activity mainly regarded non-zero baryon density QCD. A new variant of the well known Hasenfranz-Karsch action has been introduced that allows some step forward toward the determination of the critical line in the Temperature-Baryon density plane. Studying a system in an extended parameter space, an easier, and possibly safer, extrapolation to the region of non-zero baryon density, impossible to be accessed with standard numerical schemes, should be attained. A study in three dimensional Gross-Neveu model and in 4 Flavours QCD has produced encouraging results; the method and these results are the subject of a paper that has appeared in JHEP[2] and of two talks given at the LATTICE 2004 Conference[4,5].

A further report[3], in which the study of the deconfining phase transition of 4 Flavours QCD is extended in the Temperature-Chemical potential plane up to values of the quark chemical potential as large as 270 MeV, is in advanced stage of preparation. We find a clear first order line separating the usual chiral broken phase from a chiral symmetrical deconfined phase, that should be a quark-gluon plasma phase.

We plan to extend the use of this approach to the more physically interesting case of 2+1 flavours; moreover we are considering the possibility of using it for the study of condensed matter systems described by a partition function with a complex action, like the repulsive Hubbard model that is considered as a paradigm model for superconductor with high critical temperature (H-Tc superconductivity).

Journal and Proceedings publications in 2004

1. V. Azcoiti, G. Di Carlo, A. Galante, V. Laliena,
THETA DEPENDENCE OF CP⁹ MODEL
Phys. Rev. D69 (2004) 056006.
2. V. Azcoiti, G. Di Carlo, A. Galante, V. Laliena,
FINITE DENSITY QCD: A NEW APPROACH
JHEP 0412 (2004) 010
- 3) V. Azcoiti, G. Di Carlo, A. Galante, V. Laliena,
PHASE DIAGRAM OF QCD WITH FOUR QUARK FLAVOURS AT FINITE TEMPERATURE AND BARYON DENSITY
in preparation.
- 4) V. Azcoiti, G. Di Carlo, A. Galante, V. Laliena,
TESTING NEW STRATEGIES IN FINITE DENSITY
Talk presented at Lattice2004, Fermilab, June 21-26, 2004, to appear in Nucl.Phys. B(Proc.Suppl), hep-lat/0409160:.

5)V. Azcoiti, G. Di Carlo, A. Galante, V. Laliena,
NEW IDEAS IN FINITE DENSITY QCD
, Talk presented at Lattice2004, Fermilab, June 21-26, 2004, to appear in Nucl.Phys.
B(Proc.Suppl), hep-lat/0409158.

6) V. Azcoiti, G. Di Carlo, A. Galante, V. Laliena,
NEW ADVANCES IN NUMERICAL SIMULATIONS OF θ -VACUUM SYSTEMS
LATTICE 03, Tsukuba, July 2003, Nucl. Phys. B129-130 (Proc. Suppl.) (2004) 680.

4 Planck Scale Kinematics and Phenomenology

This activity during 2004 was included in IS GS11. From 2005 a new IS has been formed (GS51, national coordinator A.F.Grillo, with sections in Roma1 and Trieste) completely devoted to this research theme. and concerned the analysis of phenomenological consequences, in particular in Ultra High Energy Cosmic Ray Physics, of possible departures from (special) relativistic invariance at energy-momentum scales near the Planck Mass. The persons involved are R. Aloisio (partly, main activity in FA51), A. Galante (partly), A. Grillo and F. Mendez, in collaboration with P. Blasi (IAF, Arcetri) and P.L. Ghia (IFSI and INFN Torino).

The activities in 2004 mainly involved the analysis of the so-called Doubly (or Deformed) Special Relativity-DSR models which are momentum space relativistic theories where, apart from the (low energy) speed of light, there exist a second invariant quantity chosen to be the Planck mass. These theories are expected to incorporate some aspects of Quantum Gravity.

A. Grillo has been invited to give lectures on the subject at the 49th Karpacz School held in February 2004 in Ladek Zdnoy (Poland). A. Grillo has given an invited talk at the Vulcano 2004 workshop, while A. Galante has been invited to report at CRIS 2004 in Catania.

Journal and Proceedings publications in 2004

1. R. Aloisio, P. Blasi, A. Galante, P.L. Ghia, A.F. Grillo,
QUANTUM-GRAVITY PHENOMENOLOGY AND HIGH ENERGY PARTICLE PROPAGATION.

Nucl.Phys. Proc.Suppl. 136: 344-349, 2004 Catania 2004, "GZK and surroundings"
344-349 e-Print Archive: astro-ph/0410413

2)R. Aloisio, A. Galante, A.F. Grillo, E. Luzio, F. Mendez,
APPROACHING SPACE TIME THROUGH VELOCITY IN DOUBLY SPECIAL RELATIVITY.

Phys. Rev. D70: 125012,2004 e-Print Archive: gr-qc/0410020

3)R. Aloisio, J.M. Carmona, J.L. Cortes, A. Galante, A.F. Grillo, F. Mendez,
PARTICLE AND ANTIPARTICLE SECTORS IN DSR1 AND KAPPA-MINKOWSKI SPACE-TIME.

Published in JHEP 0405:028, 2004 e-Print Archive: hep-th/0404111

4)R. Aloisio, P. Blasi, A. Galante, A.F. Grillo,
PHENOMENOLOGY OF SPACE-TIME FLUCTUATIONS.

10th Marcel Grossmann Meeting on Recent Developments in Theoretical and Experimental General Relativity, Gravitation and Relativistic Field Theories (MG X MMIII), Rio de Janeiro, Brazil, 20-26 Jul 2003. e-Print Archive: gr-qc/0401082

5) J. Gamboa, M. Loewe, F. Mendez,

QUANTUM THEORY OF TENSIONLESS NONCOMMUTATIVE P-BRANES.

Phys.Rev.D70:106006,2004

6) Jose Manuel Carmona, Jose Luis Cortes, Ashok Das, Jorge Gamboa,

Fernando Mendez MATTER-ANTIMATTER ASYMMETRY WITHOUT DEPARTURE FROM THERMAL EQUILIBRIUM.

e-Print Archive: hep-th/0410143

7) Ashok Das, Jorge Gamboa, Fernando Mendez, Justo Lopez-Sarrion,

CHIRAL BOSONIZATION FOR NONCOMMUTATIVE FIELDS.

JHEP 0405:022,2004 e-Print Archive: hep-th/0402001