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Part A - Research Results

▷ A.1 Scientific Highlights

The research activities are summarised below under the headings of the main objectives of this network and the institution where the work was carried out. Collaborative work by members of different teams is emphasised and such publications are listed separately (A.2). Additional publications by the **young researchers** supported by the network are also given (A.2.1), as well as joint publications with other related networks (A.2.2).

(i) **Inflation**

Bonn: Nilles, Olive and **Peloso** discussed [177, 178] the production of gravitinos from the perturbative decays inflaton → inflatino + gravitino, and inflatino → inflaton + gravitino. Groot Nibbelink and van Tent studied the primordial fluctuations generated when more than one scalar field is involved during inflation [130, 188, 189].

Geneva, CERN: Chung [20] examined lensed density perturbations in brane-worlds as an alternative to perturbations from inflation.

Lancaster: Lyth and Wands proposed the 'curvaton' paradigm [101] according to which the primordial density perturbation originates from the vacuum fluctuation during inflation of a 'curvaton' field which is different from the inflaton, thus liberating inflation models from the usual COBE normalisation constraint. This may allow non-slow-roll 'thermal' inflation to originate structure, yield non-gaussianity and also give a correlated baryon or neutrino isocurvature perturbation with predicted magnitude. All these effects are observable in the forseeable future and are under intensive investigation by Lyth and **Dimopoulos**, in collaboration with Lazarides and **Ruiz de Austri** (Thessaloniki).

Dimopoulos and Valle have developed general criteria to construct unified frameworks for quintessence and inflation, together with a concrete model [187, 171].

Madrid: Garcia-Bellido [51] discussed preheating at the end of inflation as a consequence of a tachyonic mass term in the scalar field responsible for spontaneous symmetry breaking. Garcia-Bellido and collaborators also described a simple mechanism that can lead to inflation within string-based brane-world scenarios [52].

Orsay: Parry and Steer [113] analysed the requirements for successful brane gas inflation.

Oxford: A weakly coupled scalar field may not be in thermal equilibrium after inflation; Casini and Sarkar showed [17] that if such a field subsequently undergoes discrete symmetry breaking, then the different degenerate vacua are not equally populated so the domain walls which form will be 'biased' and the wall network will subsequently collapse.

Paris, Meudon/IAP: Lemonine, Martin and Uzan (Orsay) derived [93] the stress-energy tensor of a free scalar field with a general non-linear dispersion relation in curved spacetime in order to describe trans-Planckian modes during inflation. Gravitational waves of trans-Planckian momenta but subhorizon frequencies cannot account for the form of cosmic vacuum energy density observed at present, contrary to a recent claim. In pure de Sitter inflation there is no modification of the power spectrum except for a possible magnification of its overall amplitude independently of the dispersion relation.

Trieste, SISSA: Boubekeur and Tasinato pointed out [12] that the singlet nature of the inflaton field has interesting consequences in supergravity models since the allowed trilinear terms in the Kähler potential generate tadpole diagrams that modify the structure of the inflationary scalar potential yielding "Mutated Hybrid Inflation".

Trieste, ICTP: Mazumdar, Panda and Perez-Lorenzana proposed [109] a new mechanism of inflation using non-BPS $D4$ branes which decay into stable $D3$ branes via tachyon condensation. German, Mazumdar and Perez-Lorenzana showed [58] that "natural" hybrid inflation is easily incorporated in supergravity. Green and Mazumdar examined [64] in detail the dynamics, including radion stabilisation, of a hybrid inflation model where the inflaton is a gauge singlet residing in the bulk. Mazumdar and collaborators noted [2] that inflatinos produced by vacuum fluctuations during preheating do not survive long enough to pose a problem for nucleosynthsis.

Enqvist (Helsinki), Kasuya (Helsinki) and Mazumdar (Trieste, ICTP) discussed [153] the fragmentation of the inflaton condensate and argued that it can give rise to quasistable solitons and slow reheating.

Nilles (Bonn), **Peloso** *(Bonn), and Sorbo (Trieste, SISSA) studied the nonthermal production of gravitinos at preheating, which various authors had claimed to be several order of magnitude above the limit allowed by primordial nucleosynthesis. They noted [178] that in the most standard models of gravity mediated supersymmetry breakdown the fermionic field which is mostly produced at preheating is the partner of the inflaton field, while the gravitino production is well below the nucleosynthesis bound.*

Peloso *(Bonn), Sorbo (Trieste, SISSA) and collaborators studied the possible production of fermionic quanta from metric perturbations amplified during preheating and showed that this mechanism does not lead to an excessive production of gravitational relics [146].*

Jeannerot (Trieste, SISSA), Khalil and Lazarides (Thessaloniki) demonstrated [157] how to implement hybrid inflation in Pati-Salam unified theories, avoiding the cosmological disaster encountered in the standard hybrid inflationary scenario from the overproduction of monopoles at the end of inflation..

(ii) **Dark matter**

Annecy: Arbey, Lesgourgues and Salati considered [4] a complex scalar field as a candidate for the dark matter but found that there are severe difficulties when constraints from galactic dynamics and cosmology are simultaneously taken into account.

Barcelona: Massó, Rota and Zsembinszki reanalysed [103] the conditions under which a primordial thermal population of axions appears, finding a reduction of the expected density of axions from string decay. Casas studied the neutrino masses and mixings needed to explain the atmospheric and solar neutrino fluxes [149].

Bonn: Forste discussed [47] the question of the dark energy in the Universe in connection with the fine tuning problem of the cosmological constant.

Geneva, CERN: Ellis and collaborators continued their programme of constraining supersymmetric dark matter from accelerator experiments in order to estimate detection rates in dark matter experiments [33, 35, 36, 38, 39, 40]. Giudice discussed [60] alternative possibilities for dark matter assuming a low reheat temperature after inflation.

Helsinki: Enqvist, Jokinen, Multamaki and Vilja considered constraints on self-interacting dark matter made of Q-balls [43].

Ioannina: Vergados investigated [133] the modulation effect due to the Earth's motion on the direct detection rate of supersymmetric dark matter. Vergados and Owen studied [134] simultaneous density profiles and velocity distributions of galactic dark matter particles based on the Eddington theory. Gomez, Lazarides and **Pallis** analysed [172] neutralino dark matter in the context of a Pati-Salam $SU(4)_C \times SU(2)_L \times SU(2)_R$ model. Leontaris and collaborators investigated the stability of non-topological solitons which arise in various supersymmetric models due to the existence of U(1) global symmetries [94].

Madrid, Autonoma: Recent studies suggest that the process of symmetry breaking after inflation typically occurs very fast, within a single oscillation of the symmetry-breaking field, due to the spinodal growth of its long-wave modes. Garcia-Bellido showed how this sudden transition from the false to the true vacuum can induce a significant production of particles, bosons and fermions, coupled to the symmetry-breaking field, with possibly interesting consequences for the origin of supermassive dark matter and the generation of the observed baryon asymmetry through leptogenesis [53].

Oxford: The recently detected ultra-high energy cosmic rays (beyond the Greisen-Zatsepin-Kuzmin cutoff) may originate from the decays of dark matter particles with mass of order 10^{12} GeV clustered in the halo of our Galaxy. Coriano and Faraggi [25, 26] and Sarkar and Toldrà [122] calculated the expected spectra of both high energy cosmic nucleons and neutrinos, which are determined in this model by the physics of QCD fragmentation, and found encouraging agreement with the data, particularly when the effects of supersymmetry and decays into many-particle states are taken into acount. A numerical code [126, 127] was developed by Toldrà to solve the DGLAP equations which describe the QCD fragmentation process. Ibarra and Toldrà calculated [76] the flux of ultra high energy neutralinos expected in the decay of super heavy dark matter particles.

Boehm and collaborators investigated the mass and interaction cross section of dark matter candidates allowed by structure formation and showed that alternatives to cold dark matter are still viable [183, 182].

Trieste, SISSA: Ullio studied non-thermal dark matter candidates in anomaly-mediated supersymmetry breaking schemes [128]. Ullio and collaborators proposed a test of the cosmological model from the distribution of dark matter in the central part of galaxies, in particular around central supermassive black holes [129], and studied the feasibility of searching for dark matter with a novel detector of ultra-low energy antiprotons and antideutrons [110]. Ullio and collaborators also proposed [10] a novel signature for dark matter particle detection, which may be present in the extragalactic gamma-ray background.

Trieste, ICTP: Senjanovic and collaborators studied the expectations for massive neutrinos in a supersymmetric SO(10) model [7]. Mazumdar and collaborators [3] showed that Hubble-induced corrections to supersymmetric flat directions during inflation leads to the formation of Q-balls only at the weak scale, with typically small charges.

Allahverdi, Enqvist (Helsinki) and Mazumdar (Trieste, ICTP) [144] studied the possible astrophysical signatures of heavy stable relics that may arise in supergravity models.

Nihei, Roszkowski (Lancaster) and **Ruiz de Austri** *(Thessaloniki) obtained new cosmological and experimental constraints on the Constrained Minimal Supersymmetric Standard Model [166], and exact analytic expressions for neutralino WIMP pair-annihilation [164].*

Bertone (Paris, Meudon/IAP), Lopes and Silk (Oxford) used the sound speed and the density profiles inferred from helioseismic data to constrain the effect of the accretion and annihilation of supersymmetric dark matter particles on the evolution of the Sun [160]. They also showed that the annihilation of supersymmetric dark matter in the Galaxy would be enhanced in the vicinity of the central black hole [147].

Coriano, Faraggi (CERN & Oxford) and **Plumacher** *(Oxford) discussed possible metastable matter states that arise from Wilson line breaking of GUT symmetries in semi-realistic heterotic string models as candidates for the decaying dark matter particles whose decays may create UHECRS [150].*

Hansen and Silk (Oxford) and Lesgourgues (Annecy) showed [156] that a sterile keV mass neutrino is an excellent warm dark matter candidate.

(iii) **Cosmological phase transitions**

London, King's College: Gravanis and Mavromatos studied [62] supersymmetry breaking and the cosmological constant in the context of colliding brane-worlds, finding that the collision results in transfer of electric current from one brane to another. This implies departure from criticality of the string theory of matter excitations on the (observable) brane world, resulting in a relaxation to zero vacuum enegy, similar to quintessence models.

Orsay: Steer and collaborators investigated [114] all spherically symmetric fundamental monopole solutions in the $SU(5) \to SU(3) \times SU(2) \times U(1)/Z_3 \times Z_2$ symmetry breaking, finding three-fold replication of the monopoles, possibly of relevance to the family problem.

Oxford: see [17], discussed under **Inflation**.

Trieste, ICTP: Senjanovic and collaborators discussed a supersymmetric $SU(6)$ GUT with the flat direction being lifted by soft supersymmetry breaking and the doublet-triplet splitting being achieved with Higgs as a pseudo-Goldstone boson, which offers a simple solution to the false vacuum and monopole problems [5, 6].

Peloso *(Bonn) and* **Sorbo** *(Paris, Meudon/IAP) showed that excessive production of gravitational relics may occur from cosmic strings generated at the phase transition which ends hybrid inflation [165].*

(iv) **Baryogenesis**

Geneva, CERN: Chung and Dent discussed [21] Standard model baryogenesis through four-fermion operators in braneworlds.

Helsinki: Jokinen studied [78] the evolution of the MSSM Affleck-Dine fields in F-term and D-term inflation.

Marseilles: Hambye discussed [71] the possibility of inducing leptogenesis at a low scale of $\mathcal{O}$(TeV) in all existing neutrino mass models.

Oxford: Sarkar assessed what is known about the baryon asymmetry of the universe from astrophysical arguments [118]. Davidson & Ibarra deduced a lower bound on the right-handed neutrino mass for supersymmetric leptogenesis [29]. **Plumacher** and collaborators discussed the connection between neutrino mass and leptogenesis [168] and developed a novel model for baryogenesis through brane collisions [167].

Trieste, ICTP: Berezhiani, Mazumdar and Perez-Lorenzana found an interesting mechanism for generating a cosmologically significant lepton asymmetry through the evolution of sneutrino fields in a supersymmetric hybrid inflation model [9]. Mazumdar and collaborators examined the viability of the Affleck-Dine mechanism for baryogenesis under radiatively induced running of soft breaking mass-squared of the flat directions stemming from the large vacuum energy during inflation [1].

Allahverdi, Enqvist (Helsinki), Mazumdar and Perez-Lorenzana (Trieste, ICTP) presented [145] an Affleck-Dine baryogenesis model in theories with large extra dimensions.

(v) **String/M-theory cosmology**

Barcelona: Garriga and Tanaka presented a simple formalism for calculating the spectrum of perturbations and their subsequent evolution in a braneworld universe created from colliding bubbles [54]. Garriga and collaborators considered [55] a class of 5-D brane-world solutions with a power-law warp factor $a(y) \propto y^q$, and bulk dilaton with profile $\phi \propto \ln y$, where y is the proper distance in the extra dimension. They also showed [56] that in brane-world scenarios with warped extra dimensions, the Casimir force due to bulk matter fields may be sufficient to stabilize the radion field ϕ.

Bonn: Ghilencea, Groot Nibbelink and Nilles showed [61, 69, 68] that anomalies are present in several models recently proposed in the context of extra dimensions. Forste discussed the fine-tunings in models which were claimed to solve the cosmological constant problem in the context of extra dimensions [47]. Forste and Honecker showed [75, 48, 49] some explicit constructions of brane models in string theory. **Peloso** discussed the possible realization of bouncing and cyclic cosmologies in brane models [176]. Nilles reviewed [112] supersymmetry breakdown from an hidden sector. Ghilencea and Groot Nibbelink discussed [70] the field theory description of string threshold corrections. Conrad considered fractional instanton numbers in heterotic orbifolds [23, 24].

Geneva, CERN: Veneziano and collaborators studied scalar fluctuations in dilatonic braneworlds [13, 14], the causal entropy bound in weakly and strongly coupled conformal field theories in arbitrary dimensions [15], and the consequences of a runaway dilaton, in particular violations of the equivalence principle [27, 28] and quintessence [57]. Hebecker discussed [73] dynamical adjustment mechanisms for the cosmological constant and, with March-Russell, investigated the bulk black hole in Randall-Sundrum II cosmology [74].

Helsinki: Enqvist and Sloth [44] showed that the axionic isocurvature perturbations of the pre-Big Bang models can be converted to adiabatic perturbations if the axion is massive and unstable. Hassan and Sloth [72] studied the effects of transplanckian modification of dispersion relations on inflation. Enqvist, Keski-Vakkuri and Rasanen [45] explored the constraints imposed by the ekpyrotic scenario on brane matter and Hubble law. Rasanen [115] studied brane collisions in the ekpyrotic scenario. Antoniadis and **Sturani** [181] studied Higgs-graviscalar mixing in Type I string theory.

Ioannina: Kanti and Tamvakis [190] investigated the possibility of obtaining localized black hole solutions in brane worlds by introducing a dependence of the four-dimensional line element on the fifth dimension. It appears that no conventional type matter can support such dependence. Rizos and collaborators [180] carried out a systematic computation of the masses of anomalous $U(1)$ gauge fields which turn out to be quite light and capable of mediating a new non-universal repulsive force at submillimeter distances.

Lancaster: Lyth showed that the ekpyrotic model has severe difficulties in generating the primordial density perturbation, in both its original [98] and revised [99] versions.

London, King's College: Mavromatos and Diamandis [107, 108, 30, 31] studied inflationary scenaria in the context of non-critical strings. Mavromatos and Gravanis [63] studied the properties of logarithmic conformal algebras satisfied by recoil operators expressing the recoil of D(irichlet)-brane defects embedded in Robertson-Walker space times.

Oxford: Kogan and collaborators presented a generalization of the five dimensional multigravity models to six dimensions which admit solutions which do not have any negative tension branes while at the same time the branes are kept flat; this allows a theoretically and cosmologically viable realization of multigravity [82, 83]. Lukas & Skinner developed a framework for potential-driven brane-world inflation in the context of a five-dimensional brane-world model motivated from heterotic M-theory; they showed that solutions with bulk potential and both brane potentials positive exist but are always non-separating and have a non-static orbifold [97]. Santos and collaborators reexamined Wald's no-hair theorem for global anisotropy in the brane world scenarios and derived a set of sufficient conditions which must be satisfied by the brane matter and bulk metric so that a homogeneous and anisotropic brane asymptotically evolves to a de Sitter spacetime in the presence of a positive cosmological constant on the brane [117].

Orsay: Charmousis and Dufaux [19] found the general solution of a 5-dimensional spacetime with a bulk cosmological constant in the presence of a Gauss-Bonnet term and examined the consequences in brane world cosmology. **Davis** [169, 170] obtained cosmological brane world solutions with bulk scalar fields. Steer and collaborators [116] developed gauge invariant cosmological perturbation theory for braneworlds. Brax and Steer [186] discussed the cosmology of non-BPS branes.

Paris, Meudon/IAP: Langlois and **Sorbo** [173] considered cosmological two-brane models with AdS bulk for which the radion is time dependent, and computed the effective four-dimensional action for the radion.

Trieste, SISSA: Tasinato and collaborators studied [66] a model in which our universe is localized on a brane moving through a higher dimensional background, obtained by solving the equations of motion relative to the typical field content of low energy string theory. They discussed how to recover the conventional cosmology in this framework. Fabbrichesi, Piai and Tasinato considered [46] a six-dimensional model with large extra dimensions, showing that the necessary cancellation of gauge and gravitational anomalies requires the addition of Green-Schwartz fields having specific couplings with the gauge fields. These turn out to be axion fields which naturally solve the strong CP problem.

Trieste, ICTP: Youm studied various aspects of brane-world cosmology, in particular static brane configurations in the bulk background of the topological black hole in asymptotically flat spacetime [136], a scalar-tensor bimetric cosmology in the Randall-Sundrum model [137], another Randall-Sundrum model where the electric charge varies with time in the manner described by the varying fine-structure constant theory of Bekenstein [138], null bulk geodesic motion in the brane world cosmology [139], a varying electric charge brane world cosmology [140], and the Cardy-Verlinde Formula in an asymptotically de Sitter brane Universe [141, 142]. He also examined whether cosmologies with varying speed of light are compatible with the second law of thermodynamics [143].

Warsaw: Lalak [84] summarized the status of 4-D supergravities derived from warped compactifications of 5-D brane worlds which provide a framework for studying the cosmological evolution at late times. The generalized brane-bulk supergravity was constructed [184], allowing for a supersymmetric detuning between brane and bulk Lagrangians, and with flipped boundary conditions. Static cosmological solutions were found in the form of anti-deSitter foliations in detuned and flipped cases, with the radius of the orbifold stabilized. In the flipped case the cosmological solution resembling our Universe has been found — a time-dependent orbifold with repelling or attracting branes separated by a horizon. The relation between boundary terms in orbifold picture of the brane world, and boundary terms on the interval describing the same physical situations, were established [85].

Consistent string-derived models with fictitious, theory space extra dimensions were derived, and they were shown to have improved UV behaviour even in the absence of low-energy supersymmetry [185]. Such models, where gauge sectors seem to be higher-dimensional at low energies while gravity remains four-dimensional at all scales seem to be an interesting alternative to 'true' brane worlds. In particular, it was shown that such models can easily account for the aparent unification of the gauge couplings [18].

Groot Nibbelink, Nilles and Meissner (Bonn), and Olechowski (Warsaw) discussed [155, 163] the localization of bulk fields in theories with extra dimensions, an observation particularly important for a realization of the cosmological aspects of the brane world scenario. Meissner and Nilles (Bonn) and Olechowski (Warsaw) [162] studied the details of supersymmetry breakdown in theories with extra dimensions. Instabilities of bulk fields in higher dimensional cosmology were identified and studied by Groot Nibbelink and Nilles (Bonn) and Olechowski (Warsaw) [154].

Mavromatos (London, King's College) and Rizos (Ioannina) [161] continued their studies of exact solutions of string equations describing the dynamics of braneworlds embedded in higher-dimensional bulk space times. In particular, they examined the effects of higher-curvature Gauss-Bonnet terms in the efective action with dilaton and graviton fields, finding bulk naked singularity solutions which exhibit holographic properties.

(vi) **Cosmological constraints**

Barcelona: Masso and Rota [104] used the constraints arising from primordial nucleosynthesis to bound a putative electric charge density of the universe. They also worked out the bounds in models with a photon mass which allow the possibility of a charge density without large-scale electric fields. Grifols, Masso and Mohanty [65] generalized the Schwinger mechanism and calculated the probability of the decay of intense electromagnetic fields to pseudoscalar particles. Masso and collaborators [79] introduced the possibility of neutrino decay in the oscillation hypothesis and obtained a lower bound on the ratio of the lifetime to the mass by demanding that decay does not spoil the successful explanation of solar and atmospheric neutrino oscillations. Massó [105] placed severe bounds on universality violations of the couplings of ν_e, ν_μ, and ν_τ to the Z boson, thus justifying the assumption of universality that is usually made, e.g. in the analysis of neutrino oscillations.

Bonn: **Peloso** and collaborators [175] computed the precise number of effective neutrino species (relevant for CMB computations) taking into account their non instantaneous decoupling, as well as QED corrections. **Peloso** and collaborators [174] discussed possible signals in the CMB spectrum by noncommutative geometry, posing a limit on the scale of noncummutativity with respect to the horizon scale during inflation.

Granada: If there are large extra dimensions and the fundamental Planck scale is at the TeV scale, then the question arises of whether ultra-high energy cosmic rays might probe them. Masip studied energy loss from graviton mediated interactions and conclude that they cannot explain the cosmic ray events above the GZK energy limit [41].

Helsinki: Enqvist, Kurki-Suonio and Väliviita [42] found that pure isocurvature models cannot fit the CMB data even with an arbitrary value of the density parameter Ω. Giovannini. Kurki-Suonio and Sihvola [59] explored the consequences of matter-antimatter regions and gravitational waves on nuclosynthesis.

Oxford: Sarkar [120] discussed possible astrophysical tests of quantum gravity induced dispersion *in vacuo*, particularly through the effects on the kinematics of processes involving high energy cosmic radiation.

Paris, Meudon/IAP: Langlois [87] gave a critical review of what we can learn about cosmological parameters from CMB observations.

Mavromatos (London, King's College) and Ellis (Geneva, CERN) [152] continued their study of phenomenological constraints on models of non-critical string induced space-time foam in quantum gravity, the most interesting of which arise due to possible non-trivial optical properties of matter propagating in such backgrounds.

Hansen (Oxford), Petcov (Trieste, SISSA) and collaborators [151] showed that the experimentally observed large neutrino mixing ensures that effective flavor equilibrium is established between all active neutrino species well before the big-bang nucleosynthesis, so that a large neutrino chemical potential is no longer allowed.

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▷ A.2 Joint Publications and Patents

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▷ A.2.2 Joint Publications with other RTN Networks

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[181] I. Antoniadis (CERN) and **R. Sturani** (Helsinki), "Higgs-graviscalar mixing in type I string theory," Nucl. Phys. B **631** (2002) 66 [arXiv:hep-th/0201166].* [with HPRN-CT-2000-00148]

[182] C. Boehm (Oxford), P. Fayet (ENS) and R. Schaeffer (Saclay), "Constraining the strength of dark matter interactions from structure formation," arXiv:astro-ph/0205406. [with HPRN-CT-2000-00148]

[183] C. Boehm (Oxford), A. Riazuelo (Saclay), S. H. Hansen (Oxford) and R. Schaeffer (Saclay), "Interacting dark matter disguised as warm dark matter," arXiv:astro-ph/0112522. [with HPRN-CT-2000-00148]

[184] P. Brax (Saclay), A. Falkowski (Warsaw) and Z. Lalak (Warsaw), "Non-BPS branes of supersymmetric brane worlds," Phys. Lett. B **521** (2001) 105 [arXiv:hep-th/0107257].* [with HPRN-CT-2000-00148]

[185] P. Brax (Saclay), A. Falkowski (Warsaw), Z. Lalak (Warsaw) and S. Pokorski (Warsaw), "Custodial supersymmetry in non-supersymmetric quiver theories," Phys. Lett. B **538** (2002) 426 [arXiv:hep-th/0204195].* [with HPRN-CT-2000-00148]

[186] P. Brax (Saclay) and D. A. Steer (Orsay), "Non-BPS brane cosmology," JHEP **0205** (2002) 016 [arXiv:hep-th/0204120]. [with HPRN-CT-2000-00148]

[187] **K. Dimopoulos** (Lancaster) and J. W. Valle (Valencia), "Modeling quintessential inflation," arXiv:astro-ph/0111417. [with HPRN-CT-2000-00148]

[188] S. Groot Nibbelink (Bonn) and B. J. van Tent (Utrecht), "Scalar perturbations during multiple field slow-roll inflation," Class. Quant. Grav. **19**, 613 (2002) [arXiv:hep-ph/0107272].* [with HPRN-CT-2000-00131]

[189] S. Groot Nibbelink (Bonn) and B. J. van Tent (Utrecht), "Density perturbations arising from multiple field slow-roll inflation," hep-ph/0011325.* [with HPRN-CT-2000-00131]

[190] P. Kanti (CERN) and K. Tamvakis (Ioannina), "Quest for localized 4-D black holes in brane worlds," Phys. Rev. D **65** (2002) 084010 [arXiv:hep-th/0110298].* [with HPRN-CT-2000-00148]

PART B - Comparison with the Joint Programme of Work

▷ B.1 Research Objectives

The research objectives, as set down in the project programme (Annex I of the contract), are still relevant and achievable.

▷ B.2 Research Method

The research method has not changed from that described in the contract.

▷ B.3 Work Plan

The breakdown of tasks, schedule and milestones, research effort of the participants etc has not changed significantly from that described in the contract. More effort is being devoted to Task (v) "String/M-theory cosmology", than anticipated earlier, due to the explosion of interest in the cosmology of brane-world.

▷ B.4 Organisation and Management

B 4.1

The organisation is done by the coordinator through regular email and telephone contact with the Team Leaders at the major nodes as well as the institutions of the extended teams. Apart from the annual meeting of the network, many members also meet at various conferences throughout the year (see below), so there is plenty of opportunity for forming collaborations.

The central source for all information concerning the network is the WWW homepage (`http://www-thphys.physics.ox.ac.uk/users/SubirSarkar/eunet.html`) which lists all network members (with hyperlinks to their individual homepages, email addresses and publications on electronic databases), network meetings (with appropriate hyperlinks), the network's annual reports, publications etc. Links are also provided to related networks in the HCM programme. The homepages of the participating institutions (and the names and emails of the Team Leaders) are given on the front page (so are not listed here).

B 4.2

The following international conference was organised *jointly* with our sister network *'Physics Across the Present Energy Frontier'* (HPRN-CT-2000-00148).

• "From the Planck Scale to the Electroweak Scale - Supersymmetry & Brane Worlds", Kazimierz, Poland, 25-29 May 2002 (`http://www.fuw.edu.pl/ susy/Planck02.html`)
This attracted 100 participants from the two networks and from other institutions in Europe and USA. An important discussion theme was "Cosmology in brane worlds and the role of supersymmetry". An informal meeting of the 20 network members present was also held, in order to plan the forthcoming mid-term review meeting.
- Speakers: P. Binetruy (Orsay), L. Boubekeur (SISSA), **P. Bucci (Warsaw)**, P. Chankowski

(Warsaw), E. Dudas (Orsay), A. Faraggi (Oxford), S. Forste (Bonn), **N. Irges** (Madrid), K. Kowalska (Warsaw), Z. Lalak (Warsaw), D. Lyth (Lancaster), R. Matyszkiewicz (Warsaw), K. Meissner (Warsaw), H-P. Nilles (Bonn), M. Olechowski (Bonn), J. Pawelczyk (Warsaw), **M. Peloso (Bonn)**, S. Pokorski (Warsaw), A. Pomarol (Barcelona), L. Roszkowski (Lancaster), S. Sarkar (Oxford), K. Tamvakis (Ioannina), G. Tasinato (SISSA).

• "Journee des Lacs Alpins de Cosmologie" (`wwwlapp.in2p3.fr/lesgourg/JLAC/jlac.html`)
— 3rd Journée (CERN, 20 Nov 2001)
— 4th Journée (Université de Geneve, 24 May 2002)
In order to reinforce the cohesion of the network members at the CERN and Annecy nodes, Annecy continued to organise regular meetings intended mainly for CERN, Annecy and University of Geneva cosmologists (with participation also from Lausanne and Grenoble).

Other meetings which network members helped to organise and/or participated in were:

- The Cosmological Model, Les Arcs, 16-23 Mar 2002
  (`http://moriond.in2p3.fr/J02/`)
  - D. Langlois, Meudon/IAP (plenary speaker), D. Lyth, Lancaster (plenary speaker [100]), J. Silk, Oxford (plenary speaker)

- SUSY01: The 9th International Conference on Supersymmetry and Unification of Fundamental Interactions, Dubna, 11-17 Jun 2001
  (`http://susy.dubna.ru/`)
  - Z. Lalak, Warsaw (speaker), H-P. Nilles, Bonn (plenary speaker), D. Lyth, Lancaster (plenary speaker), M. Quiros, Madrid (plenary speaker), G. Senjanovic, ICTP (plenary speaker)

- 13th Rencontres de Blois: Frontiers of the Universe, Chateau de Blois, 17-23 Jun 2001
  (`http://wwwusr.obspm.fr/confs/blois2001.html`)
  - S. Sarkar, Oxford (invited speaker [118]), J. Silk, Oxford (invited speaker

- String Phenomenology and Searches Beyond the Standard Model, Brighton, 4-5 Jul 2001
  (`http://www.pact.cpes.sussex.ac.uk/SummerFest/`)
  - R. Toldrà, Oxford (speaker)

- International Europhysics Conference on High Energy Physics, Budapest, 12-18 Jul 2001
  (`http://www.hep2001.elte.hu/`)
  - P. Binetruy, Orsay (plenary speaker), A. Hebecker, CERN (plenary speaker), S. Sarkar, Oxford (plenary speaker [119])

- International Workshop on Neutrino Oscillations, Venice, 24-26 Jul 2001
  (`http://axpd24.pd.infn.it/NO-VE/NO-VE.html`)
  - M. Fabbrichesi, SISSA (invited speaker), S. Petcov, SISSA (invited speaker)

- COSMO-01: International Workshop on Particle Physics and the Early Universe, Rovaniemi, 30 Aug-4 Sep 2001
  (`http://www.physics.helsinki.fi/cosmo01/index.html`)
  - S. Groot Nibbelink, Bonn (speaker [130]), H-P. Nilles, Bonn (IAC and plenary speaker [178]), **M. Peloso**, Bonn (speaker [178]), S. Sarkar, Oxford (IAC and plenary speaker [121]), L. Roszkowski, Lancaster (IAC and plenary speaker), R. Toldrà, Oxford (speaker [127])

- Summer Insitute on Elementary Particle Physics, Corfu, 30 Aug-20 Sep 2001
  (`http://theory.physics.uoi.gr/corfu2001/`)
  - N. Mavromatos, KCL (lecturer), G. Ross, Oxford (lecturer)

- 4th meeting of the RTN network "Across the Present Energy Frontier: Probing the Origin of mass", Corfu, 10-13 Sep 2001
(`http://theory.physics.uoi.gr/corfu2001/`)
- L. Boubekeur, SISSA (speaker), A. Faraggi, Oxford (speaker), D. Ghilencea, Bonn (speaker), S. Pascoli, SISSA (speaker), M. Piai, SISSA (speaker), G. Tasinato, SISSA (speaker).

- First Aegean School on Cosmology, Samos, 21-29 Sep 2001
- N. Mavromatos, KCL (lecturer)

- DESY Theory Workshop on "Gravity and Particle Physics", Hamburg, 9-12 Oct
(`http://www.desy.de/desy-th/workshop.01/index.html`)
- P. Binetruy, Orsay (plenary speaker), J. March-Russell, CERN (plenary speaker), H-P. Nilles, Bonn (plenary speaker), M. Piai, SISSA (speaker), J. Silk, Oxford (plenary speaker), G. Tasinato, SISSA (speaker).

- Workshop on Ultra High Energy Cosmic Rays, 3-7 Dec 2001
(`http://wwwlapp.in2p3.fr/UHECR2001/`)
- F. Ferrer, Oxford (speaker), R. Jeannerot, SISSA (speaker), R. Toldrà, Oxford (speaker)

- International Workshop on Neutrino Oscillations and their Origin, Tokyo, 5-8 Dec 2001
- S. Petcov, SISSA (invited speaker).

- 30th Conference on High Energy Physics and Cosmology, Coral Gables, 12-16 Dec 2001
(`http://www.globalfoundationinc.org/`)
- J. Vergados, Ioannina (speaker)

- First IUCAA Meeting on the Interface of Gravitational and Quantum Realms, Pune, 17-21 Dec 2001
- S. Sarkar, Oxford (plenary speaker [120])

- Cairo International Conference on High-Energy Physics, Cairo, 9-14 Jan 2001
- J. Casas, Madrid (invited speaker [149]), R. Jeannerot, SISSA (invited speaker [157])

- 36th Rencontres de Moriond on Electronic Correlations: From Meso-Physics to Nano-Physics, Les Arcs, 20-27 Jan 2001
- J. Garcia-Bellido, Madrid (speaker) [51]

- 30th International Meeting on Fundamental Physics, Jaca (Spain), 28 Jan-1 Feb
(`http://www.unizar.es/imfp2002/`)
- J. Garcia-Bellido, Madrid (speaker), E. Massó, Barcelona (speaker)

- Dark 2002: 4th International Conference on Dark Matter in Astro and Particle Physics, Cape Town, 4-9 Feb 2002
(`http://dark2002.phy.uct.ac.za/`)
- C. Boehm, Oxford (speaker), J. Ellis, CERN (plenary speaker [33]) H-P. Nilles, Bonn (plenary speaker), L. Roszkowski, Lancaster (plenary speaker), J. Vergados, Ioannina (speaker)

- DM2002: 5th International Symposium on Sources and Detection of Dark Matter and Dark Energy in the Universe, Marina del Rey, 20-22 Feb 2002
(`http://www.physics.ucla.edu/hep/DarkMatter/dm2002.html`)
- L. Roszkowski, Lancaster (invited speaker).

- Nordic Workshop on Astroparticle Physics and Cosmology, Copenhagen, 1-2 Mar 2002 (`http://www.nordita.dk/ steen/nordic/nordic.html`)
  - S. Sarkar, Oxford (invited speaker)
- 37th Rencontres de Moriond: Electroweak Interactions and Unified theories, 9-16 Mar 2002 (`http://moriond.in2p3.fr/EW/2002/`)
  - C. Boehm, Oxford (invited speaker), M. Quiros, Madrid (invited speaker), L. Roszkowski, Lancaster (invited speaker)
- (Alternative) Dark Matter, Cosmic Structure and the Early Universe, Ringberg Castle, 8-12 Apr 2002 (`http://www.mpa-garching.mpg.de/ banerjee/workshop/`)
  - C. Boehm, Oxford (speaker), **M. Plumacher**, Oxford (invited speaker), P. Ullio, SISSA (invited speaker)
- Annual Meeting of the Hellenic Society for the Study of High Energy Physics, Patras, 25-27 Apr 2002
  (`http://leandros.physics.upatras.gr/hep2002/`)
  - N. Mavromatos, KCL (speaker), J. Rizos, Ioannina (speaker), K. Tamvakis, Ioannina (speaker)
- QCD and gauge theory dynamics in the RHIC era, Santa Barbara, 27 Apr-23 May 2002 (`http://www.kitp.ucsb.edu/activities/qcd02/?id=8)`
  - C P Korthals Altes, Marseille (invited speaker)

B 4.3

Secondments:

H. Casini (Oxford) moved for the second year of his fellowship (supported by CONICET Argentina) to the Centre de Physique Theorique, Marseille, a node of the French Team. J. Lesgourgues (Annecy) moved to Geneva to become a CERN fellow in Oct 2001. I. Kogan (Oxford) is spending his sabbatical year (2001-02) in Paris and interacting closely with the members of the Orsay Team. J. Rizos (Ioannina) also took his sabbatical (2001-02) in Paris.

Konstantinos Pallis having obtained his PhD at Thessalonki moved to become a network fellow at SISSA in Feb 2002. **Lorenzo Sorbo** having obtained his PhD at SISSA moved to become a network fellow at Meudon/IAP in Oct 2001. **Roberto Ruiz de Austri**, having obtained his PhD at Lancaster, moved to become a network fellow at Thessalonki in Oct 2001.

Michael Plümacher, who will soon be finishing as network fellow at Oxford, will move to Geneva as a CERN fellow in Oct 2002. **Riccardo Sturani** moved to Helsinki from Oxford in Oct 2001 to become a network fellow.

Study visits:

K. Dimopoulos (Lancaster) spent 5 weeks in Spring 2002 collaborating with G. Lazarides at Thessaloniki. S. Forste (Bonn) visited Warsaw in Feb 2001. C. Korthals Altes (Marseille) made 3 visits to Geneva in Autumn 2001 and Spring 2002 for collaboration with M. Laine (CERN). N. Mavromatos (KCL) made several visits to CERN and to Ioannina, as well as to Paris. H.P. Nilles (Bonn) visited CERN in Mar 2002. M. Olechowski (Bonn) visited Warsaw in Feb 2002. **M. Peloso** (Bonn) spent Apr 2001 at CERN to continue work with various collaborators and visited Oxford in Mar and Nov 2001. M. Quiros (Madrid) visited Oxford in Jan 2002. J. Rizos (Ioannina) made several visits to King's College, London to collaborate with N. Mavromatos.

J.D. Vergados (Ioannina) visited the USA during 10-16 Dec 2001 to collaborate with P. Nath (North Eastern University) and to speak at the "Coral Gables Conference on Elementary Particle & Astrophysics" [132], with the prior approval of the EC (telefax dt 3/12/01, D(01)537223, Research DG–3/TrpAppVerg.doc).

▷ B.5 Training

B.5.1

All vacant positions for young researchers were advertised on the EC website (`http://improving.cordis.lu/rtn/` as well as on the website of the host institution. In addition email alerts were sent to comprehensive lists of researchers in both Europe and the USA with a request to draw these vacancies to the attention of prospective applicants. (Posts were not advertised in magazines such as *Nature* due to the high cost of such advertisements.) Typically over ten applications were received from qualified candidates for each post advertised.

B.5.2

During this year most of the post-doctoral positions in the network were filled from Autumn 2001 and further appointments made for the few unfilled positions from Autumn 2002. A complete list of all young researchers with their appointment dates is given below:

1. Oxford: Dr Michael Plumacher (1/10/00-30/9/02)
   Lancaster: Dr Kostas Dimopoulos (1/10/01-30/9/03)
2. Bonn: Dr Marco Peloso (1/11/00-31/10/02)
3. Geneva: N.A.
4. Helsinki: Dr Riccardo Sturani (1/10/01-30/9/03)
5. Ioannina: Dr Itsaso Olasagasti (1/11/01-1/11/03)
   Thessaloniki: Dr Roberto Ruiz de Austri (1/11/01-1/11/03)
6. Madrid: Dr Nikolaos Irges (1/10/01-30/9/03)
   Barcelona: Dr Pasquale Di Bari (1/10/02-30/9/04)*
7. Orsay: Dr Stephen Davis (1/9/01-31/8/03)
   Meudon/IAP: Dr Lorenzo Sorbo (1/10/01-30/9/03)
8. Trieste: Dr Constantinos Pallis (1/2/02-31/1/04), Dr Werner Rodejohann (1/10/02-30/9/04)*
   ICTP: Dr Marieke Postma (1/10/02-30/9/04)*
9. Warsaw: Dr Patrizia Bucci (01/10/01-30/09/02)

*Note that the appointments marked * extend beyond the nominal end of the network contract in June 2004. Hence we intend to request an extension of the contract period until end-Dec 2004.*

Young Researchers Financed by the Contract						
	Deliverable (in Person-Months)			Financed till 6/02 (in Person-Months)		
Participant	Pre-doc	Post-doc	Total	Pre-doc	Post-doc	Total
1. UOXF.DR	0	48	48	0	28	28
2. DPUB	0	24	24	0	19	19
3. CERN	0	0	0	0	0	0
4. UHEL	0	24	24	0	8	8
5. U.IOANNINA	0	48	48	0	14	14
6. CSIC	0	48	48	0	8	8
7. LPT	0	48	48	0	17	17
8. SISSA	0	72	72	0	4	4
9. UW	0	24	24	0	8	8
Totals	0	336	336	0	106	106

B.5.3

The young researchers supported by the network have, in most cases obtained their PhDs at other nodes of the network (Pallis, Peloso, Sorbo, Ruiz de Austri), or at institutions which have close links with the network nodes (Bucci, Davis, Di Bari, Dimopoulos, Irges, Plümacher, Sturani). Thus they were already familiar with the activities of the network and did not require any special measures for integration.

B.5.4

The training of the young researchers is largely left to the host nodes. As is common practice for young post-docs, they are are free to pursue their research programme, often forming collaborations with other network members at the annual meetings and at other conferences and schools, as well as with non-network people at their host institutions. They are encouraged to represent the network at conferences and are given priority for presenting their work at network meetings. They are also given the opportunity to undertake additional responsibilities such as graduate lecturing, supervision of undergraduate projects etc to develop their teaching skills.

B.5.5

All appointments must be made in accordance with the rules and regulations of the host institution, which usually specify that there must be no bias with regard to gender, religious beliefs etc. Three of the 14 young researchers appointed (Bucci, Olassagasti, Postma) are women — while this is far short of 50%, it perhaps represents the fraction of female researchers in this subject as a whole.

B.5.6

The programme at the annual schools reflects the multidisciplinarity within the network, with lectures on both astrophysical and particle physics issues. This is particularly useful for young researhers and graduate students in the network, who have usually been trained in one or the other area. Several collaborations have been formed between astrophysicists and particle physicists in the network (e.g. [146, 182, 183]).

B.5.7

There are no links to industrial and commercial enterprises.

▷ B.6 Difficulties

The major difficulty has been in appointing young researchers in accuordance with the schedule specified in the contract. Although the nominal start date of network activities was 1 June 2000, the advance payment was not received from the EC until Nov that year so that it was not possible for most Teams to make appointments until Oct 2001 (see B.5.2), keeping in mind that post-doc appointments normally begin in the Autumn. Consequently there was an under-spend in the first year (1/6/00–31/5/01), resulting in a rather low first periodic payment. Several Teams who have made appointments in Autumn 2001 (in particular Greece and Poland) are now facing financial difficulties, since their host institutions are unwilling to provide support in advance for the appointed young researchers.

Secondly, some members have moved to different institutions (e.g. A. Masiero, Leader of the Italian Team at SISSA, Trieste moved to the University of Padua in 2001). It appears that short of renegotiating the contract, there is no means to retain within the network valuable members who may need to move for professional reasons.

Part C - Summary Reports by Young Researchers

The questionnaire will be filled in by the 2 young researchers named below whose contracts terminate soon, and sent separately:

1. **Marco Peloso**, Italian, 1/11/00-31/10/02, University of Bonn, Germany
2. **Michael Plumacher**, German, 1/10/00-30/9/02, University of Oxford, UK