

Supersymmetry and the Early Universe

Mid-Term Review Report

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PART A - RESEARCH RESULTS

A.1 Scientific Highlights

The collaborative research activities are summarised below under the headings of the main objectives of the network and such publications are listed separately (A.2). Additional publications by the young researchers supported by the network are also listed (A.2.1), as well as joint publications with other related networks (A.2.2). A full list of all relevant publications by the network is given in Appendix 1.

(i) Inflation

Nilles and **Peloso** (Bonn) and **Sorbo** (Trieste & Paris) clarified the question of gravitino production during preheating following the end of inflation by doing the first explicit nonperturbative calculation in a model with broken supersymmetry [49, 50, 67, 68]. It was found that in models with gravity mediated supersymmetry breaking, the fermionic field which is mostly produced at preheating is the partner of the inflaton field, while the production of gravitinos is well below the bound set by nucleosynthesis arguments. They also developed a general formulation for the calculation of particle production at preheating in the two-field case, which can be applied to hybrid inflation models. **Peloso** and **Sorbo** 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 [3, 150].

A SUSY GUT model based on the Pati-Salam gauge group $SU(4)_c \times SU(2)_L \times SU(2)_R$ was presented by Jeannerot (Trieste) and Lazarides (Thessaloniki) [31, 32]. This leads naturally to smooth hybrid inflation, avoiding the cosmological disaster encountered in the standard hybrid inflationary scenario from the overproduction of monopoles at the end of inflation. Successful reheating is also achieved, satisfying the thermal gravitino constraint.

Lyth proposed the ‘curvaton’ paradigm 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 [119]. 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 potentially observable and are under intensive investigation by Lyth and **Dimopoulos** (Lancaster) [40], in collaboration with Lazarides and **Ruiz de Austri** (Thessaloniki).

Enqvist (Helsinki), Kasuya (Helsinki) and Mazumdar (Trieste) discussed the fragmentation of the inflaton condensate and argued that it can give rise to quasi-stable solitons and slow reheating [21].

(ii) Dark matter

Enqvist (Helsinki) and Mazumdar (Trieste) studied in detail the possible astrophysical signatures of heavy stable relic particles which arise in supergravity models [2].

Sigl and Bertone (Paris) showed with Silk (Oxford) that the accretion of dark matter particles by the massive black hole present at the center of our Galaxy creates a region of very high density where the dark matter annihilation rate is considerably increased, thus facilitating detection [4, 5, 6]. Bertone and Silk 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 [40].

Coriano, Faraggi (CERN/Oxford) and **Plümacher** (Oxford) discussed possible meta-stable 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 ultra-high energy cosmic rays [13]. Ferrer (Barcelona) and Evans and Sarkar (Oxford) calculated

the expected anisotropy of such cosmic rays for various models of the dark halo and showed that it would be detectable by the forthcoming Pierre Auger Observatory [20].

Roszkowski (CERN & Lancaster) proposed, with Kim (Lancaster), the possibility that relic axinos constitute the dark matter [14]. They also continued a programme of accurately calculating the relic density of neutralino dark matter subject to all laboratory bounds, with Nihei (Lancaster) and **Ruiz de Austri** (Lancaster & Thessaloniki) [36, 46, 47, 48, 52].

Hansen and Silk (Oxford) and Lesgourgues (Annecy) showed that a sterile keV mass neutrino is an excellent candidate for warm dark matter [30].

(iii) Cosmological phase transitions

Laine (CERN) and Rummukainen (Helsinki) made a detailed study of non-perturbative aspects of the electroweak phase transition in two-doublet models [38].

Tkachev (CERN) and Garcia-Bellido (Madrid) studied the dynamics of symmetry breaking and tachyonic preheating [25].

Peloso (Bonn) and **Sorbo** (Paris) showed that excessive production of gravitational relics may occur from strings generated at the phase transition which ends hybrid inflation [51].

Casini (Marseille) and Sarkar (Oxford) found that if a weakly coupled scalar field undergoes discrete symmetry breaking after inflation, then the different vacua are not equally populated so the domain walls formed will be ‘biased’ and the wall network will subsequently collapse [23].

(iv) Baryogenesis

Jeannerot (Trieste) and Lazarides (Thessaloniki) showed that in their SUSY GUT inflationary model, adequate baryogenesis via primordial leptogenesis occurs consistently with the Solar and atmospheric neutrino oscillation data [31].

Enqvist (Helsinki), Mazumdar and Perez-Lorenzana (Trieste) presented a model for Affleck-Dine type baryogenesis in theories with large extra dimensions [1].

(v) String/M-theory cosmology

Forste, Lavignac and Nilles (Bonn), and Lalak (Bonn & Warsaw) presented sum rules that have to be fulfilled by the bulk and brane tensions in order to obtain consistent solutions to the cosmological constant problem, and gave a critical evaluation of the mechanism of self-tuning [79]. Lalak, with Falkowski and Pokorski (Warsaw) presented a five dimensional gauged supergravity which admits the Randall-Sundrum solution as a BPS vacuum with vanishing energy [23], and discussed how to obtain four-dimensional supergravities from five-dimensional brane worlds [24].

Ellis (CERN) and Mavromatos (KCL) studied the effects of quantum gravity induced space-time foam on particle interactions and the consequences for ultra-high energy cosmic ray propagation [16, 17], and also discussed the possible connection between string theory and cosmological vacuum energy [18].

Leontaris (Ioannina) and Mavromatos (KCL) constructed a metric that describes the distortion of space-time surrounding a D(irichlet)-brane (solitonic) defect after being struck by another D-brane [39]. By viewing our four-dimensional universe as such a struck brane, the appearance of a band of massive Kaluza-Klein excitations for the bulk graviton was noted. Mavromatos and Rizos (Ioannina) considered the $\mathcal{O}(\alpha')$ string effective action, with Gauss-Bonnet curvature-squared and fourth-order dilaton-derivative terms [42, 43]. They showed that a non-factorizable metric of the Randall-Sundrum type, with four-dimensional conformal factor $e^{-2k|z|}$, can be a solution of the pertinent equations of motion.

Kortals-Altes (Marseille) and Laine (CERN) studied the fate of discrete symmetries when gauge degrees of freedom are located on a topological defects (as in the case of branes) [37].

Kachelreiss (CERN) and **Plümacher** (Oxford) found that the enhancement of the neutrino scattering cross-section (through exchange of Kaluza-Klein gravitons) in TeV-scale quantum gravity models is inadequate to enable cosmic neutrinos to be the primaries for ultra-high energy cosmic rays [33, 34].

Binetruy (Orsay) and Silk (Oxford) studied the constraints imposed by the CMB and gravitational lensing on brane models where gravity at very large (cosmological) distances is five-dimensional [7].

Abel (Orsay) and Kogan (Oxford) examined the cosmological effects of the Hagedorn phase in brane-world models and found that even in the absence of a cosmological constant, winding modes cause a negative 'pressure' that can drive brane inflation [70].

Pokorski (Warsaw) and Quiros (Madrid) collaborated on studying brane effects on extra dimensional scenarios [11].

Groot Nibbelink, Nilles and Meissner (Bonn), and Olechowski (Warsaw) discussed 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 [29, 45]. Meissner and Nilles, with Olechowski studied the details of supersymmetry breakdown in theories with extra dimensions [44]. Instabilities of bulk fields in higher dimensional cosmology were identified and studied by Groot Nibbelink and Nilles with Olechowski [28].

(vi) **Cosmological constraints**

Brax (CERN) and Martin and Riazuelo (Paris) collaborated on the constraints on quintessence models from the CMB [9, 10].

Mavromatos (KCL) and Ellis (CERN) 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 [19].

Hansen (Oxford), Petcov (Trieste) and collaborators [15] 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.

A.2 Joint Publications and Patents

- [1] R. Allahverdi, K. Enqvist (Helsinki), A. Mazumdar (ICTP) and A. Perez-Lorenzana (ICTP), "Baryogenesis in theories with large extra spatial dimensions," Nucl. Phys. B **618** (2001) 277 [arXiv:hep-ph/0108225].*
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- [3] B. A. Bassett, **M. Peloso** (Bonn), L. Sorbo (SISSA) and S. Tsujikawa, "Fermion production from preheating-amplified metric perturbations," Nucl. Phys. **B622** (2002) 393 [arXiv:hep-ph/0109176].*
- [4] G. Bertone (Paris), G. Sigl (Paris) and J. Silk (Oxford), "Annihilations from the galactic centre," Proc. 3rd International Workshop On The Identification Of Dark Matter (World Scientific, 2000) p.311 [arXiv:astro-ph/0011553].
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- [6] G. Bertone (Paris), G. Sigl (Paris) and J. Silk (Oxford), "Annihilation Radiation from a Dark Matter Spike at the Galactic Centre," arXiv:astro-ph/0203488.
- [7] P. Binetruy (Orsay) and J. Silk (Oxford), "Probing large-distance higher-dimensional gravity with cosmic microwave background measurements," Phys. Rev. Lett. **87** (2001) 031102 [arXiv:astro-ph/0007452].
- [8] P. Binetruy (Orsay), R. Schaeffer, J. Silk (Oxford) and F. David, "The Primordial Universe: Proc. 71st Les Houches Summer School On Physics," (Springer-Verlag, 2000).
- [9] P. Brax (CERN), J. Martin (Paris) and A. Riazuelo, "Exhaustive study of cosmic microwave background anisotropies in quintessential scenarios," Phys. Rev. D **62** (2000) 103505 [arXiv:astro-ph/0005428].

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- [11] M. Carena, A. Delgado, J. Lykken, S. Pokorski (warsaw), M. Quiros (Madrid) and C. E. Wagner, “Brane effects on extra dimensional scenarios: A tale of two gravitons,” Nucl. Phys. B **609** (2001) 499 [arXiv:hep-ph/0102172].*
- [12] J. A. Casas (Madrid) and A. Ibarra (Oxford), “Massive neutrinos and lepton-flavour violating processes,” arXiv:hep-ph/0109161.
- [13] C. Coriano, A. E. Faraggi (Oxford & CERN) and M. Plümacher (Oxford) “Stable superstring relics and ultrahigh energy cosmic rays,” Nucl. Phys. B **614** (2001) 233 [arXiv:hep-ph/0107053].*
- [14] L. Covi, H. B. Kim (Lancaster), J. E. Kim and L. Roszkowski (Lancaster & CERN), “Axinos as dark matter,” JHEP **0105** (2001) 033 [arXiv:hep-ph/0101009].
- [15] A. D. Dolgov, S. H. Hansen (Oxford), S. Pastor, S. T. Petcov (SISSA), G. G. Raffelt and D. V. Semikoz, “Cosmological bounds on neutrino degeneracy improved by flavor oscillations,” Nucl. Phys. B **632** (2002) 363 [arXiv:hep-ph/0201287].
- [16] J. R. Ellis (CERN), N. E. Mavromatos (KCL) and D. V. Nanopoulos, “How large are dissipative effects in noncritical Liouville string theory?,” Phys. Rev. D **63** (2001) 024024 [arXiv:gr-qc/0007044].
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- [18] J. R. Ellis (CERN), N. E. Mavromatos (KCL) and D. V. Nanopoulos, “String theory and an accelerating universe,” arXiv:hep-th/0105206.
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- [21] K. Enqvist (Helsinki), S. Kasuya (Helsinki) and A. Mazumdar (ICTP), “Reheating as a surface effect,” arXiv:hep-ph/0204270.*
- [22] K. Enqvist, S. Kasuya and A. Mazumdar, “Inflatonic solitons in running mass inflation,” Phys. Rev. D **66** (2002) 043505 [arXiv:hep-ph/0206272].*
- [23] A. Falkowski (Warsaw), Z. Lalak (Bonn & Warsaw) and S. Pokorski (Warsaw), “Five-dimensional gauged supergravities with universal hypermultiplet and warped brane worlds,” Phys. Lett. B **509** (2001) 337 [arXiv:hep-th/0009167].*
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- [30] S. H. Hansen (Oxford), J. Lesgourgues (Annecy), S. Pastor and J. Silk (Oxford), “Closing the window on warm dark matter,” Mon. Not. Roy. Astron. Soc. **333** (2002) 544 [arXiv:astro-ph/0106108].
- [31] R. Jeannerot (SISSA), S. Khalil and G. Lazarides (Thessaloniki), Phys. Lett. B **506** (2001) 344 [arXiv:hep-ph/0103229].*
- [32] R. Jeannerot (SISSA), S. Khalil and G. Lazarides (Thessaloniki), “Monopole problem and extensions of supersymmetric hybrid inflation,” arXiv:hep-ph/0106035.*
- [33] M. Kachelriess (CERN) and M. Plümacher (Oxford), “Ultrahigh energy neutrino interactions and weak-scale string theories,” Phys. Rev. D **62** (2000) 103006 [arXiv:astro-ph/0005309].
- [34] M. Kachelriess (CERN) and M. Plümacher (Oxford), “Remarks on the high-energy behaviour of cross-sections in weak-scale string theories,” [arXiv:hep-ph/0109184].*

- [35] 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].*
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- [44] K. A. Meissner (Bonn), H. P. Nilles (Bonn) and M. Olechowski (Warsaw), “Brane induced supersymmetry breakdown and restoration,” hep-th/0205166.
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- [49] H. P. Nilles (Bonn), **M. Peloso** (Bonn) and L. Sorbo (SISSA), “Nonthermal production of gravitinos and inflatinos,” *Phys. Rev. Lett.* **87** (2001) 051302 [arXiv:hep-ph/0102264].*
- [50] H. P. Nilles (Bonn), **M. Peloso** (Bonn) and L. Sorbo (SISSA), “Coupled fields in external background with application to nonthermal production of gravitinos,” *JHEP* **0104** (2001) 004 [hep-th/0103202].*
- [51] **M. Peloso** (Bonn) and L. Sorbo (Paris), “Moduli from cosmic strings,” hep-ph/0205063.*
- [52] L. Roszkowski (CERN/Lancaster), **R. Ruiz de Austri** (Lancaster) and T. Nihei, “New cosmological and experimental constraints on the CMSSM,” *JHEP* **0108** (2001) 024 [arXiv:hep-ph/0106334].

A.2.1 Additional Publications by Young Researchers of the Network

- [53] P. Binetruy, C. Charmousis, **S. C. Davis** and J. F. Dufaux (Orsay), “Avoidance of naked singularities in dilatonic brane world scenarios with a Gauss-Bonnet term,” to appear in *Phys. Lett. B* [arXiv:hep-th/0206089].
- [54] W. Buchmuller and **M. Plümacher** (Oxford), “Neutrino masses and the baryon asymmetry,” *Int. J. Mod. Phys. A* **15** (2000) 5047 [arXiv:hep-ph/0007176].
- [55] W. Buchmuller and **M. Plümacher** (Oxford), “Spectator processes and baryogenesis,” *Phys. Lett. B* **511** (2001) 74 [arXiv:hep-ph/0104189].*
- [56] M. Bastero-Gil, E. J. Copeland, J. Gray, A. Lukas and **M. Plümacher** (Oxford), “Baryogenesis by brane-collision,” arXiv:hep-th/0201040.*
- [57] W. Buchmuller, P. Di Bari and **M. Plümacher** (Oxford), “Cosmic microwave background, matter-antimatter asymmetry and neutrino masses,” arXiv:hep-ph/0205349.*
- [58] **S. C. Davis** (Orsay), “Brane cosmology solutions with bulk scalar fields,” *JHEP* **0203** (2002) 058 [arXiv:hep-ph/0111351].
- [59] **S. C. Davis** (Orsay), “Generalised Israel junction conditions for a Gauss-Bonnet brane world,” arXiv:hep-th/0208205.*

- [60] **K. Dimopoulos** (Lancaster), “Models of quintessential inflation,” arXiv:astro-ph/0111500.
- [61] D. Langlois and **L. Sorbo** (Paris), “Effective action for the homogeneous radion in brane cosmology,” arXiv:hep-th/0203036.
- [62] D. Langlois, **L. Sorbo** (Paris) and M. Rodriguez-Martinez, “Cosmology of a brane radiating gravitons into the extra dimension,” arXiv:hep-th/0206146.
- [63] F. Lizzi, G. Mangano, G. Miele and **M. Peloso** (Bonn), “Cosmological perturbations and short distance physics from noncommutative geometry,” JHEP **0206** (2002) 049 [arXiv:hep-th/0203099].*
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- [66] S. Mukherji and **M. Peloso** (Bonn), “Bouncing and cyclic universes from brane models,” hep-th/0205180.*
- [67] H. P. Nilles, K. A. Olive and **M. Peloso** (Bonn), “The inflatino problem in supergravity inflationary models,” Phys. Lett. **B522** (2001) 304 [hep-ph/0107212].*
- [68] H. P. Nilles and **M. Peloso** (Bonn), “Nonthermal production of gravitinos and inflatinos in the inflationary universe,” Contribution to the Proceedings of Cosmo 01 hep-ph/0111304.*
- [69] **L. Sorbo** (Paris), “Fermion Preheating: Analytical Results,” Nucl. Phys. Proc. Suppl. **95** (2001) 86.

A.2.2 Joint Publications with other RTN Networks

- [70] S. A. Abel (Orsay), K. Freese and I. I. Kogan (Oxford), “Hagedorn inflation of D-branes,” JHEP **0101** (2001) 039 [arXiv:hep-th/0005028]. [with FMRX-CT-96-0096]
- [71] I. Antoniadis (CERN), E. Kiritsis (Paris, ENS) and J. Rizos (Ioannina), “Anomalous U(1)s in type I superstring vacua,” Nucl. Phys. B **637** (2002) 92 [arXiv:hep-th/0204153].* [with HPRN-CT-2000-00148]
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- [73] 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]
- [74] 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-2000-00124]
- [75] 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]
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- [78] **K. Dimopoulos** (Lancaster) and J. W. Valle (Valencia), “Modeling quintessential inflation,” arXiv:astro-ph/0111417.* [with HPRN-CT-2000-00148]
- [79] S. Forste (Bonn), Z. Lalak (Warsaw), S. Lavignac (Bonn & Saclay) and H. P. Nilles (Bonn), “The cosmological constant problem from a brane-world perspective,” JHEP **0009** (2000) 034 [arXiv:hep-th/0006139]. [with ERBFMRX-CT96-0090]
- [80] S. Groot Nibbelink (Bonn) and B. J. van Tent (Utrecht), “Scalar perturbations during multiple field slow-roll inflation,” Class. Quant. Grav. **19** (2002) 613 [arXiv:hep-ph/0107272].* [with HPRN-CT-2000-00131]
- [81] 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]

PART B - COMPARISON WITH THE PROJECT PROGRAMME

B.1 Project Objectives

The research objectives set down in Annex I of the contract are still relevant and achievable.

B.2 Research Method and Work Plan

The research method and work plan have not changed significantly from that described in the contract.

B.3 Schedule and Milestones (where relevant)

As discussed in A.1 (v), the breakdown of tasks, schedule and milestones have changed a little from that envisaged in the contract in that more effort is being devoted to “String/M-theory cosmology” than anticipated due to the explosion of interest in the cosmology of brane-world.

B.4 Research Effort of the Participants

There have been no significant variations between the professional effort contributed by the individual teams to the joint programme of work against that foreseen in the contract.

B.5 Networking Activities

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) spent his sabbatical year (2001-02) in Paris 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 Paris 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, having spent 2 years as a 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” [156], with the prior approval of the EC.

Network meetings:

We were committed to hold a Meeting Of Team Leaders to fix research tasks, collaborations, appointment of young researchers, education and outreach activities within 1 month of the Start Date. This was held at CERN (during the SUSY’01 conference) on 28 Jun 2001, with the participation of 30 network members. The Team Leaders presented overviews of the activities in their respective teams to the entire group, followed by a closed meeting at which administrative issues were discussed.

We were also committed to hold the First Network School/Meeting, with lectures by both Network Scientists and invited outside experts, as well as seminars by young researchers and reports from the Team Leaders, *within 1 year of the Start Date*. This was also held at CERN, 18-22 Apr 2001 and attended by about 70 people. The programme consisted of topical lectures in the mornings and specialised seminars in the afternoons. Copies of the lectures were distributed to all participants and a Discussion Forum was set up on the network's webpage.

The following scientific meetings were organised under the aegis of the network:

- “International workshop on Physics and Astrophysics of Extra Dimensions”, College de France, Paris, 9 May-22 Jun 2001 (<http://www.iap.fr/users/sigl/extradim.html>)
- Organised by the Orsay and Paris nodes. The idea was to host a two-month long meeting in Paris where world experts could be present for periods of time ranging from one week to one month to discuss the most recent issues in the field. This attracted 180 participants. The first period was concluded by a three-day meeting (28 May-1 June) on “Ultra High Energy Cosmic Rays”, while the second period was concluded by a week (18-22 Jun) devoted to “Cosmology”.

- “Les Journées des Lacs Alpains de Cosmologie”
(http://www.lapp.in2p3.fr/~lesgourgues/frame_science2.html)
▷ 1st Journée (Université de Geneve, 16 Jan 2001)
▷ 2nd Journée (LAPP, Annecy, 22 May 2001)
▷ 3rd Journée (CERN, 20 Nov 2001)
▷ 4th Journée (Université de Geneve, 24 May 2002)

In order to reinforce the cohesion of network members at the CERN and Annecy nodes, Annecy has been organising regular meetings (every four months) intended mainly for CERN, Annecy and University of Geneva cosmologists (with participation also from Lausanne and Grenoble).

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. Boubekur (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).

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

- International Workshop on Strong and Electroweak Matter, Marseilles, 14-17 Jun 2000
- C. Korthals-Altes, Marseille (Chair)
- SUSY 2K, Geneva, 26 Jun-1 Jul 2000 (<http://wwwth.cern.ch/susy2k/susy2k.html>)
- P. Binetruy, Orsay (plenary speaker), P. Brax, CERN, S. Davidson, Oxford (speaker), J. Ellis, CERN (LOC), G. Giudice, CERN (LOC), R. Jeannerot, ICTP, M. Kachelriess, CERN (speaker), H.B. Kim, Lancaster (speaker), M. Laine, CERN (speaker), Z. Lalak, Warsaw (speaker), G. Leontaris, Ioannina, D. Lyth, Lancaster (speaker), J. March-Russell, CERN (LOC), A. Masiero, SISSA (plenary speaker), H-P. Nilles, Bonn (speaker), **M. Plümacher**,

Oxford (speaker), S. Pokorski, Warsaw (speaker), M. Quirós, Madrid (plenary speaker), J. Rizo, Ioannina, L. Roszkowski, Lancaster (speaker), S. Sarkar, Oxford (speaker), G. Veneziano, CERN (organiser),

- Conference on Cosmology and Particle Physics, Verbier, 17-28 Jul 2000 (<http://mpej.unige.ch/kunze/capp2000/final/capp2000.html>)
- Invited speakers: J. Garcia-Bellido, Madrid, M. Kachelriess, CERN, M. Laine, CERN, J. March-Russell, CERN
- Thirty Years of SUSY, Minneapolis, 13-15 Oct 2000 (<http://www.tpi.umn.edu/susy30.html>)
- Invited Speakers: J. Ellis, CERN, A. Masiero, SISSA, H-P. Nilles, Bonn
- 36th Rencontres de Moriond on Electronic Correlations: From Meso-Physics to Nano-Physics, Les Arcs, 20-27 Jan 2001 (<http://www.lps.u-psud.fr/moriond01/>)
- J. Garcia-Bellido, Madrid (speaker) [67]
- 37th Karpacz Winter School, 6-15 Feb 2001 (<http://www.ift.uni.wroc.pl/karp37/>)
- Z. Lalak, Warsaw (lecturer)
- Workshop: Supersymmetric Models & String Theory in Cosmology, Heidelberg, 4-7 Apr 2001 (http://www.thphys.uni-heidelberg.de/weinstoc/ws_ssc.html)
- Speakers: S. Groot-Nibbelink, Bonn, R. Jeannerot, Trieste, A. Masiero, Trieste, H.P. Nilles, Bonn (co-organiser), M. Olechowski, Warsaw, **M. Peloso**, Bonn, **M. Plümacher**, Oxford, M. Quiros, Madrid, S. Sarkar, Oxford,
- Planck'01, La Londe les Maures, 1-16 May 2001 (<http://www.esf.org/>)
- R. Jeannerot, SISSA (speaker), D. Lyth, Lancaster (plenary speaker), Z. Lalak, Warsaw (plenary speaker), J. March-Russell, CERN (plenary speaker), A. Masiero, SISSA (plenary speaker), H-P. Nilles, Bonn (plenary speaker), S. Pokorski, Warsaw (plenary speaker), M. Quiros, Madrid (Vice-Chair & plenary speaker), G. Ross, Oxford (plenary speaker), G. Senjanovic, ICTP (plenary speaker), L. Sorbo, SISSA (speaker), K. Tamvakis, Ioannina (plenary speaker) G. Tasinato, SISSA (speaker),
- IPPP Workshop on Phenomenology of Beyond the Standard Model, Durham, 6-11 May 2001 (<http://www.ipp.dur.ac.uk/BSM/bsmindex.html>)
- Lecturers: P. Binetruy, Orsay, A. Masiero, SISSA, H-P. Nilles, Bonn, S. Pokorski, Warsaw, M. Quiros, Madrid, L. Roszkowski, Lancaster
- SUSY01: The 9th International Conference on Supersymmetry and Unification of Fundamental Interactions, Dubna, 11-17 Jun 2001 (<http://susy.dubna.ru/>)
- P. Binetruy, Orsay (IPC), J. Ellis (IAC), A. Falkowski, Warsaw (speaker), G. Giudice (IAC), Z. Lalak, Warsaw (plenary speaker), H-P. Nilles, Bonn (IPC & plenary speaker), M. Quiros, Madrid (plenary speaker), G. Ross, Oxford (IAC), 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>)
- Invited speakers: S. Sarkar, Oxford [140], J. Silk, Oxford
- 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/>)
- Plenary speakers: P. Binetruy, Orsay, A. Hebecker, CERN, S. Sarkar, Oxford [141]
- International Workshop on Neutrino Oscillations, Venice, 24-26 Jul 2001 (<http://axpd24.pd.infn.it/NO-VE/NO-VE.html>)
- Invited speakers: M. Fabbrichesi, SISSA, S. Petcov, SISSA

- M Theory Cosmology, Cambridge, 21-25 Aug 2001 (<http://www.damtp.cam.ac.uk/user/mt-cosmo/>)
- Invited speakers: P. Binetruy, Orsay, J. Garriga, Barcelona
- 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 [154]), H-P. Nilles, Bonn (IAC & plenary speaker [68]), **M. Peloso**, Bonn (speaker [68]), S. Sarkar, Oxford (IAC & plenary speaker [143]), L. Roszkowski, Lancaster (IAC & plenary speaker), R. Toldrà, Oxford (speaker [149])
- Summer Insitute on Elementary Particle Physics, Corfu, 30 Aug-20 Sep 2001 (<http://theory.physics.uoi.gr/corfu2001/>)
- Lecturers: N. Mavromatos, KCL, G. Ross, Oxford
- 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/>)
- Speakers: L. Boubekour, SISSA, A. Faraggi, Oxford, D. Ghilencea, Bonn, S. Pascoli, SISSA, M. Piai, SISSA, G. Tasinato, SISSA.
- 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 2001 (<http://www.desy.de/desy-th/workshop.01/index.html>)
- P. Binetruy, Orsay (lecturer) 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://wwlapp.in2p3.fr/UHECR2001/>)
- Speakers: F. Ferrer, Oxford, R. Jeannerot, SISSA , R. Toldrà, Oxford
- 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 [142])
- Cairo International Conference on High-Energy Physics, Cairo, 9-14 Jan 2002
- J. Casas, Madrid (invited speaker [12]), R. Jeannerot, SISSA (invited speaker [32])
- 30th International Meeting on Fundamental Physics, Jaca (Spain), 28 Jan-1 Feb 2002 (<http://www.unizar.es/imfp2002/>)
- Speakers: J. Garcia-Bellido, Madrid, E. Massó, Barcelona
- 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 [43]) 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)

- ESO-CERN-ESA Symp. on Astronomy, Cosmology and Fundamental Physics, 4-7 Mar 2002 (<http://www.eso.org/gen-fac/meetings/symp2002/>)
- P. Binetruy, J. Ellis (plenary speaker)
- 37th Rencontres de Moriond: Electroweak Interactions and Unified theories, 9-16 Mar 2002 (<http://moriond.in2p3.fr/EW/2002/>)
- Invited speakers: C. Boehm, Oxford, M. Quiros, Madrid, L. Roszkowski, Lancaster
- XIV Workshop on Beyond the Standard Model, Bad Honnef, 11-14 Mar 2002 (<http://www.physik.uni-halle.de/Fachgruppen/Theorie/qft/BadHonnef/BH02/>)
- Speakers: H-P. Nilles, Bonn, S. Forste, Bonn, A. Hebecker, CERN, M. Olechowski, Bonn
- The Cosmological Model, Les Arcs, 16-23 Mar 2002 (<http://moriond.in2p3.fr/J02/>)
- D. Langlois, Paris (IPC & plenary speaker), D. Lyth, Lancaster (plenary speaker [118]), J. Silk, Oxford (plenary speaker)
- (Alternative) Dark Matter, Cosmic Structure and the Early Universe, Ringberg Castle, 8-12 Apr 2002 (<http://www.mpa-garching.mpg.de/banerjee/workshop/>)
- Invited speakers: C. Boehm, Oxford, **M. Plümacher**, Oxford, P. Ullio, SISSA
- Annual Meeting of the Hellenic Society for the Study of High Energy Physics, Patras, 25-27 Apr 2002 (<http://leandros.physics.upatras.gr/hep2002/>)
- Speakers: N. Mavromatos, KCL, J. Rizos, Ioannina, K. Tamvakis, Ioannina
- 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)
- COSMO-02: International Workshop on Particle Physics and the Early Universe, Chicago, 18-21 Sep 2002 (<http://pancake.uchicago.edu/cosmo02>)
- IAC: J. Ellis, CERN, K. Enqvist, Helsinki, D. Lyth, Lancaster, H-P. Nilles, Bonn, L. Roszkowski, Lancaster, Plenary Speakers: L. Roszkowski, Lancaster, G. Sigl, Paris, Speakers: **K. Dimopoulos**, Lancaster, F. Ferrer, Oxford
- International School on CP Violation, Baryogenesis and Neutrinos, Prerow, 15-21 Sep 2002 (<http://topas.physik2.uni-rostock.de/prerow2002/>)
- **M. Plümacher**, Oxford (Lecturer)

B.6 Network Organisation and Management

B.7 Cohesion with Less Favoured Regions and Associated States

One of our teams is based in Greece (Ioannina and Thessaloniki) and another in Poland (Warsaw). Our colleagues at these institutions are internationally recognised as the leading researchers in their respective geographical regions and moreover they have closely collaborated with other network members in the past (e.g. in the TMR network ‘*Beyond the Standard Model*’, ERBFMRX-CT96-0090 and the HCM network ‘*Flavour Dynamics*’, CHRX-CT93-0132). Thus no special provision was felt to be necessary for their special provision into the network.

However the need to promote their existing strengths further in view of their relative isolation is acknowledged inasmuch as the Warsaw team was invited to organise the PLANCK-02 conference (“Supersymmetry & Brane Worlds”, Kazimierz, 25-29 May 2002) which was sponsored jointly by this network and our sister network ‘*Physics Beyond the Present Energy Frontier*’ (HPRN-CT-2000-00148). This was an extremely well organised and highly successful meeting attended by nearly 100 participants, including many leading researchers from the USA, and boosted the already impressive reputation of the Warsaw group even further. Similarly the Greek team has been invited to host one of the annual network schools, perhaps in 2004.

B.8 Connections to Industry

None.

PART C - TRAINING

C.1 Appointment of Young Researchers

Young Researchers Financed by the Contract						
Participant	Untill 30.09.02 (Person-Months)			Contract Deliverable (Person-Months)		
	Pre-doc	Post-doc	Total	Pre-doc	Post-doc	Total
1. UOXF.DR	0	36	36	0	48	48
2. DPUB	0	23	23	0	24	24
3. CERN	0	0	0	0	0	0
4. UHEL	0	12	12	0	24	24
5. U.IOANNINA	0	22	22	0	48	48
6. CSIC	0	12	12	0	48	48
7. LPT	0	25	25	0	48	48
8. SISSA	0	8	8	0	72	72
9. UW	0	12	12	0	24	24
Totals	0	150	150	0	336	336

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.

All the Teams are now on track to deliver (or even exceed) the number of person-months of training specified in the Contract. However because the postdoc hiring cycle typically begins in the autumn, three of the appointments to be made this year will need to continue by 4 months beyond the nominal end-date of the network (31 May 2004). One of these appointments is at Barcelona (Team 6) and two are at Trieste (Team 8) — see Part F.

C.2 Training Programme

The young researchers supported by the network have, in many 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 (Bucci, Sturani). Thus they were already familiar with the activities of the network and did not require any special measures for integration.

All appointments must be made in accordance with the rules and regulations of the host institutions, 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.

The training of the young researchers is largely left to the host nodes. As is common practice for young post-docs, they 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.

The programme at the annual schools reflects the multidisciplinary within the network, with lectures on both astrophysical and particle physics issues. This is particularly useful for young researchers 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. [3, 73, 74]).

C.3 Factual Information on the Young Researchers

Name	Nationality	Age	Start Date	End Date	Category	Speciality	Place of Work	Country	Previous Exp.
Patrizia Bucci	Italian	32	01/10/01	30/09/03	postdoc	P-01/08	Warsaw	PO	1
Stephen Davis	British	28	01/09/01	31/08/03	postdoc	P-01/08	Orsay	FR	-
Konstantinos Dimopoulos	Greek	32	01/10/01	30/09/03	postdoc	P-01/08	Lancaster	UK	2
Nikolaos Irges	Greek	36	01/10/01	30/9/03	postdoc	P-01/08	Madrid	ES	-
Itsaso Olasagasti	Spanish	30	01/11/01	01/11/03	postdoc	P-01/08	Ioannina	GR	-
Constantinos Pallis	Greek	31	01/02/02	31/01/04	postdoc	P-01/08	Trieste	IT	3
Marco Peloso	Italian	27	01/11/00	31/10/02	postdoc	P-01/08	Bonn	DE	4
Michael Plümacher	German	29	01/10/00	30/09/02	postdoc	P-01/08	Oxford	UK	-
Roberto Ruiz de Austri	Spanish	31	01/11/01	01/11/03	postdoc	P-01/08	Thessaloniki	GR	5
Lorenzo Sorbo	Italian	28	01/10/01	30/09/03	postdoc	P-01/08	Paris	FR	6
Riccardo Sturani	Italian	27	01/10/01	30/09/03	postdoc	P-01/08	Helsinki	FI	7

1. Obtained PhD in Padua (node of HPRN-CT-2000-00148)
2. Was postdoc in Valencia (node of HPRN-CT-2000-00148)
3. Obtained PhD in Thessaloniki
4. Obtained PhD in Trieste
5. Obtained PhD in Lancaster
6. Obtained PhD in Trieste
7. Obtained PhD in Pisa (node of HPRN-CT-2000-00148)

PART D - SKETCHES OF THE YOUNG RESEARCHERS

Patrizia Bucci received her PhD from the University of Padua, Italy (2001). Her thesis was on “*Finite Temperature Field Theory and its Applications to Cosmological Problems*”. In particular in collaboration with M. Pietroni [1] she discussed the problem of defining a number density for interacting heavy particles in a thermal bath and the cosmological consequences coming from suggesting a new definition. At present, as a network postdoc at Warsaw, she is working on supersymmetry breakdown at finite temperature in the context of ‘brane worlds’, in particular on the analogy between finite temperature susy breaking and the Scherk-Schwarz mechanism in extra-dimensional models (with Z. Lalak), and on cosmological solutions in brane worlds (with Z. Lalak and S. Pokorski).

- [1] **P. Bucci** and M. Pietroni, Phys. Rev. D **63** (2001) 045026 [arXiv:hep-ph/0009075].
 [2] **P. Bucci** and M. Pietroni, Proc. International Workshop on Particle Physics and the Early Universe (COSMO-01), Rovaniemi, Finland, 30 Aug - 4 Sep 2001 [arXiv:hep-ph/0111375].

Stephen C. Davis received his PhD from DAMTP at Cambridge University, UK (September 1998). His research was on “*Cosmic Strings*”, and conserved fermion currents on these, particularly in Grand Unified and supersymmetric theories. He has been a postdoctoral fellow at Swansea University, UK (1999), where he became interested in braneworld cosmologies, including those with scalar fields [1, 2, 3, 4]. He is currently a network fellow at LPT, Orsay, France and has recently started looking at the implications of string theory inspired higher order curvature terms in brane models [5]. As well as a diverse range of brane world models, he is also working on a supersymmetric axion cosmic string model, and fermion bound states on electroweak cosmic strings.

- [1] **S. C. Davis**, Phys. Lett. B **499** (2001) 179 [arXiv:hep-ph/0010255].
 [2] **S. C. Davis**, W. B. Perkins, A. C. Davis, and I. R. Vernon, Phys. Rev. D **63** (2001) 083518 [arXiv:hep-ph/0012223].
 [3] **S. C. Davis**, JHEP **0203** (2002) 054 [arXiv:hep-th/0106271].
 [4] **S. C. Davis**, JHEP **0203** (2002) 058 [arXiv:hep-ph/0111351].
 [5] P. Binetruy, C. Charmousis, **S. C. Davis** and J. F. Dufaux, Phys. Lett. B, in press [arXiv:hep-th/0206089].

Konstantinos Dimopoulos received his PhD from the University of Cambridge, UK in 1998. His research was on “*Superconducting Cosmic Strings and Primordial Magnetic Fields*”, focussing on the growth of the coherence length of primordial magnetic fields in the early universe [1], in particular for inflationary models [2]. He also studied the evolution of a network of overdamped superconducting cosmic strings [3] and the consequences on structure formation, CMB anisotropy and baryogenesis [4]. Finally he investigated the gravitational field of a superconducting string, which may generate vortical motions on the plasma and produce thereby primordial magnetic fields that can explain the magnetic fields of the galaxies [5]. He has been a postdoctoral fellow at IFIC, University of Valencia/CSIC, Spain from 1999 to 2001, where, in a collaboration with J.W.F. Valle, he studied ways to unify inflation and quintessence in a single theoretical framework [6]. Further, in collaboration with A.C. Davis, T. Prokopec and O. Törnkvist, he has investigated the possibility to gravitationally generate a primordial magnetic field in inflation by scalar electrodynamics [7] and by breaking naturally the conformal invariance of the Z-boson field [8]. In [8] he has also studied the possible amplification of such fields by parametric resonance effects during preheating, in the framework of F-term supersymmetric hybrid inflation. Since Oct 2001 he has been a network fellow at Lancaster University, working with D.H. Lyth on the implications of the curvaton hypothesis on inflationary model-building. In particular they are collaborating with G. Lazarides and R. Ruiz de Austri at the University of Thessaloniki on studying curvaton dynamics and also producing a particular curvaton model which accounts for the Peccei-Quinn symmetry and solves the μ -problem of supersymmetry. In addition he continues to pursue the study of quintessential inflation in the context of brane cosmology, in collaboration with R. Hawkins (Queen Mary College, London).

- [1] **K. Dimopoulos** and A. C. Davis, Phys. Lett. B **390** (1997) 87 [arXiv:astro-ph/9610013].
- [2] A. C. Davis and **K. Dimopoulos**, Phys. Rev. D **55** (1997) 7398 [arXiv:astro-ph/9506132].
- [3] **K. Dimopoulos** and A. C. Davis, Phys. Rev. D **57** (1998) 692 [arXiv:hep-ph/9705302].
- [4] **K. Dimopoulos** and A. C. Davis, Phys. Lett. B **446** (1999) 238 [arXiv:hep-ph/9901250].
- [5] **K. Dimopoulos**, Phys. Rev. D **57** (1998) 4629 [arXiv:hep-ph/9706513].
- [6] **K. Dimopoulos** and J. W. Valle, Astropart. Phys. **18** (2002) (in press) [arXiv:astro-ph/0111417].
- [7] A. C. Davis, **K. Dimopoulos**, T. Prokopec and O. Törnkvist, Phys. Lett. B **501** (2001) 165 [arXiv:astro-ph/0007214].
- [8] **K. Dimopoulos**, T. Prokopec, O. Törnkvist and A. C. Davis, Phys. Rev. D **65** (2002) 063505 [arXiv:astro-ph/0108093].

Nikos Irges received his PhD from University of Florida, Gainesville, USA, in August 1999. His PhD research, under P. Ramond, involved supersymmetric model building and consequences of supersymmetry breaking [1, 2]. He did his first postdoc at the University of Colorado, Boulder, USA during 1999–2001. There, in collaboration mainly with S.P. de Alwis, he looked into the cosmological constant problem from the point of view of string theory brane worlds [3, 4]. In the fall of 2001 he joined the IEM/CSIC Madrid group as a network postdoc, where in collaboration with G.V. Gersdorff and M. Quiros he has been analyzing quantum field theory on orbifolded higher dimensional gauge theories [5, 6]. He also participated in a collaboration with D. Ghilencea, L. Ibanez and F. Quevedo that analyzed phenomenologically U(1) gauge symmetries arising in intersecting D-brane models [7].

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Itsaso Olasagasti received her PhD from the University of the Basque Country, Bilbao, Spain (1999) [1, 2]. She has been a Postdoctoral Fellow at the Institute of Cosmology, Tufts University, USA (2000). During her stay at Tufts she has become involved in the study of braneworld models in collaboration with A. Vilenkin. In particular, her emphasis has been on the construction of global branes as global defects [3, 4] with codimension $n \geq 3$. At present, as a network postdoc at Ioannina, she is collaborating in a project with K. Tamvakis (Ioannina) and P. Kanti (Cern) on black holes with a 4-D Schwarzschild

metric located on a brane within a bulk of higher codimension, studying in particular the occurrence of naked singularities and their significance [5]. She is also involved in the study of dynamical thick wall models, both in 5 and higher dimensions and their localization properties on various fields.

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Constantinos Pallis received his PhD from Thessaloniki University, Greece (July 2000) with the title “*Phenomenology and Cosmology of Supersymmetric Grand Unified Theories*”. In particular, he studied, in collaboration with M.E. Gómez (Lisbon) and G. Lazarides (Thessaloniki), a version of CMSSM supplemented by the assumption of Yukawa coupling exact [1] or quasi [2] unification. At present, as a network postdoc at SISSA, he is collaborating in a project on low reheating scale in CMSSM with A. Masiero and A. Riotto (Padova). He is also interested in cold dark matter [3, 4], inflation, neutrino astrophysics etc.

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Marco Peloso received his Ph.D. from SISSA, Trieste, under the supervision of Prof A Masiero, with the thesis “*New perspectives for the first second: preheating of fermions and extra-dimensions*”. Mainly active in the area of (nonperturbative) reheating after inflation, he also made some studies on the cosmology of models with extra dimensions and on the implications of measurements of CMB anisotropies. After becoming a network Fellow at Bonn he worked with Prof H-P Nilles and **L Sorbo** (Trieste and Paris) on the production at preheating of gravitinos in models with gravitationally mediated supersymmetry breakdown. He has been also active in other areas of theoretical cosmology.

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Michael Plümacher received his PhD from the University of Hamburg, Germany in 1998. His PhD research was on the “*Baryon Asymmetry of the Universe*”, in particular its connection with neutrino properties in the leptogenesis scenario [1]. He has been a Postdoctoral Fellow at the University of Pennsylvania, Philadelphia, USA from 1998 to 2000, where, in a collaboration with M. Cvetič, P. Langacker and J. Wang he studied the low energy phenomenology of Type IIB orientifold string theories[2]. Generically,

these string theories predict the existence of additional neutral gauge bosons with flavour non-universal couplings which could lead to a rich phenomenology at low energies [3]. Further he became interested in the possible connection between string theories and ultra-high energy cosmic rays [4]. Since October 2000 he has been a network fellow at the University of Oxford. There he has worked with A. Faraggi and C. Coriano (Lecce) on the implications of heterotic string models for cosmic ray physics[5]. Further, he has continued investigating the connection between neutrino properties and the baryon asymmetry of the universe, together with W. Buchmüller (DESY) and P. Di Bari (DESY/Barcelona) [6].

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Roberto Ruiz de Austri received his PhD from Lancaster University, UK (October 2001). His PhD research was on “*Supersymmetric Dark Matter*”. In particular, he studied, in collaboration with L. Roszkowski, several aspects of the neutralino as the main candidate for Cold Dark Matter [1, 2, 3]. Since his appointment as a network fellow in Thessaloniki, he is collaborating in a project on inflation with G. Lazarides(Thessaloniki), D. Lyth(Lancaster) and K. Dimopoulos(Lancaster). Apart from SUSY Dark Matter and Inflation, he is interested in various aspects of brane cosmology, unification models etc.

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Lorenzo Sorbo received his PhD from SISSA/ISAS, Trieste, Italy (October 2001). His PhD research was on “*Brane Cosmology and Preheating after Inflation*”. In particular, during the last year spent as a PhD student in Trieste he studied, in collaboration with H.P. Nilles and **M. Peloso** (Bonn), the question of gravitino production in inflationary models [1], introducing a general formalism for the analysis of preheating in the case of several coupled fields [2]. In collaboration with **M. Peloso**, B. Bassett and S. Tsujikawa, he studied the production of fermions induced by metric perturbations amplified at preheating [3]. He has carried his research in Paris as a network fellow mainly on the subject of ‘brane cosmology’, where in collaboration with D. Langlois he studied the four-dimensional effective action for the Randall-Sundrum model [4] and (also in collaboration with M. Rodriguez-Martinez) he analysed in a self-consistent way the emission of bulk gravitons in models with an infinite extra dimension [5]. He has also studied, in collaboration with **M. Peloso**, the cosmological effects of the emission of scalar moduli by cosmic strings [6]. He is currently collaborating with L. Boubekeur (Trieste), **M. Peloso** and S. Davidson in the analysis of the effect of preheating on supersymmetric models of leptogenesis.

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Riccardo Sturani did his PhD (1998-2000) at the Scuola Normale Superiore di Pisa, Italy, being Michele Maggiore his advisor. He is currently waiting to defend his thesis. He is now a network fellow at the University of Helsinki (2001). His studies involve string cosmology, with particular focus on the pre-big bang model, which he studied also in collaboration with Ram Brustein [1] and the phenomenology of large extra dimensions [2]. Presently in Helsinki he is studying string cosmological models, in particular he is interested in obtaining an inflating Universe within the context of a string derived model.

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APPENDIX 1: PUBLICATIONS BY NETWORK MEMBERS

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APPENDIX 2: OUTREACH PROGRAMME

Given the interest of the general public in cosmological matters, an ‘outreach’ programme is being developed. Network members have written commentaries on scientific developments for both professional publications such as CERN Courier and Physics World, as well as articles for popular magazines such as New Scientist. Key scientific findings of the Network have been publicised through such channels. Many Network members also give non-technical talks to schools, teachers and the general public. Young researchers are particularly encouraged to engage in such activities in order to communicate their enthusiasm and the intellectual excitement of the subject to the broader audience whose support for fundamental research is essential in the long run. We list below a representative selection of such activities.

Commentaries in professional publications: P. Binetruy (Orsay) wrote a popular article titled “*How many dimensions to our universe?*” for Europhysics News 33 (2002) 54. J. Ellis (Geneva) wrote a number of articles for CERN Courier (e.g. “*Science knows no boundaries*”, Jan/Feb 2002) and Physics World (e.g. review of “*Facing Up: Science and its Cultural Adversaries*”, Apr 2002). N. Mavromatos (KCL) wrote a review article on “*Testing models for quantum gravity*” for CERN Courier (Sep 2002). S. Sarkar (Oxford) wrote a news report on “*Could the end be in sight for ultrahigh-energy cosmic rays?*” for Physics World (Sep 2002).

Talks to general audiences: **P. Bucci** (Warsaw) gave an overview of ‘Finite-temperature Field Theory’ for non-specialists, at the Warsaw University Science Worker’s House in the Summer Term 2002. **K. Dimopoulos** talked about ‘A Voyage in the Cosmos through Space and Time’ to the Hellenic Society of Lancaster University in Jan 2002. J. Ellis (Geneva) gave many popular talks, e.g. to physics teachers visiting CERN on ‘Matter, Antimatter and the Universe’ (Mar 2002). Z. Lalak (Warsaw) gave a popular lecture on brane worlds at the biannual meeting of the Polish Physical Society at Torun, September 2001. S. Sarkar (Oxford) gave several popular talks on ‘Seeing the edge of the universe’ and ‘The Road to Quantum Gravity’ (Georgia Tech Summer School, Worcester College, Oxford, Jul 2001, ‘Oxford Access Scheme’ Summer School, Aug 2001, Institute of Physics Schools Lecture, Shrewsbury School, Sep 2001, Institute of Physics ‘Young Physicist’s Conference’, Oxford, Nov 2001, Science Society, New College, Oxford, Nov 2001, Linacre College, Oxford, Feb 2002, St Edward’s School, Oxford, Mar 2002, Taunton School, May 2002).