Supersymmetry and the Early Universe

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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**

Orsay: Crotty, Lesgourgues and Pastor [19] placed bounds on the cosmological background of relativistic particles using WMAP observations of the CMB.

Trieste: **Postma** [78] considered model-independent constraints on the 'curvaton' in SUSY theories, finding that non-renormalizable operators, residual isocurvature perturbations, and thermal effects constrain this scenario severely. In addition, the curvaton field may decay prematurely through resonance effects [127].

Cline (CERN), Crotty & Lesgourgues (Annecy) [97] discussed whether the anomalously small CMB quadrupole moment measured recently by WMAP might suggest new physics.

Crotty & Lesgourgues (Annecy) and Garcia-Bellido (Madrid) [98] showed that the WMAP observations of the CMB set stringent bounds on isocurvature perturbations.

Enqvist & Kasuya (Helsinki) and Mazumdar (ICTP) suggested a new mechanism for reheating through evaporation of a surface charge of a fragmented inflaton condensate, resulting in a low reheat temperature which avoids the gravitino and moduli problems. They also studied chaotic inflation with a running mass and showed that in such models the Universe could be reheated slowly via surface evaporation of inflatonic lumps [105].

Enqvist, Jokinen & Kasuya (Helsinki) and Mazumdar (ICTP) [37] examined whether flat directions in the MSSM could act as the 'curvaton' and generate the observed adiabatic density perturbation, given the constraint from damping of the fluctuations. A working example was found by employing the $n = 9$ MSSM flat direction if the inflaton is in the hidden sector. Enqvist (Helsinki) and Mazumdar (ICTP) [107] wrote an invited review on the cosmology of flat directions.

Enqvist (Helsinki), Mazumdar (ICTP) and **Postma** *(ICTP) [108] considered the possibility of generating adiabatic density perturbations from spatial fluctuations in the inflaton decay rate, due to quantum fluctuations of light moduli fields coupling to the inflaton; however the perturbations are damped too much for such models to work.*

Jeannerot (SISSA), Khalil and Lazarides (Thessaloniki) [117] considered a 'shifted hybrid inflation' scenario based on a renormalizable superpotential in an extension of the SUSY Pati-Salam model. The observed density perturbation is generated when the inflaton field valueis close to the Planck scale, but with SUGRA corrections under control.

(ii) **Dark matter**

Bonn: Nilles and Kim [57] proposed a new candidate for 'quintessence' based on the 'model-independent axion' of heterotic string theory. The scheme accounts for a realistic abundance of dark matter and dark energy in a single model containing the 'quint-axion' as well as the usual 'invisible QCD-axion' related to the solution of the strong CP-problem.

Ioannina: Vergados [91] showed that dark matter recoil detectors can extend their sensitivity by exploiting the correlation of the expected signal with the Sun's motion; the forward-backward asymmetry with respect to this direction is large and the modulation observed in the orthogonal plane is direction dependent and can exceed 20%.

Oxford: Boehm and Fayet [131] discussed the constraints on scalar dark matter, while Boehm, Ensslin and Silk examined whether dark matter particles can be light. Taylor and Silk [89] studied the implications of clumping on the annihilation signal from CDM particles. Evans, Ferrer and Sarkar [38] showed that such clumping cannot explain the observed clustering of ultra-high energy cosmic rays if these arise from the decay of superheavy dark matter particles.

SISSA: Ullio and collaborators [25] further developed the DarkSUSY code for obtaining the thermal relic abundance of the LSP in the MSSM, including coannihilations, to an accuracy of 1%. The identification of a possible dark matter annihilation signal in the extragalactic γ-ray background was studied, with estimates for the flux obtained from cosmological N-body simulations of hierarchical clustering in CDM cosmologies, including the appropriate forms for the mass function, the DM density profiles and the relation between virial masses and concentration parameters [90]. Data from the EGRET survey was searched for possible dark matter annihilation signals from the Galactic centre [11].

Pallis [73] considered the MSSM with the assumption of $b-\tau$ Yukawa coupling unification and using a moderate gaugino non-universality in order to accomodate the constraints from the b mass and muon anomalous magnetic moment. This allows the possibility of new co-annihilation pheonomena leading to an acceptable dark matter abundance, consistent with constraints from $b \to s + \gamma$ decays and other accelerator data.

Profumo [79] studied the implications of minimal non-universal boundary conditions in the sfermion soft SUSY breaking masses of mSUGRA (motivated by the multiplet structure of $SU(5)$), imposing asymptotic $b - \tau$ Yukawa coupling unification. Cosmological and phenomenological constraints, including the recent results from WMAP, were used to determine the allowed parameter space of the models considered.

Damour, Kogan (Oxford) and Papazoglou (Bonn) [99, 100] studied the possibility of explaining the dark energy of the Universe in a 'bigravity' model containing a massive graviton. They also discussed the static spherically symmetric solutions generated by stars with regular interiors in such a theory.

Gómez, Lazarides (Thessaloniki) and **Pallis** *(SISSA) [113] found that the CMSSM with $\mu < 0$, supplemented by a Yukawa quasi-unification condition (which allows an acceptable b mass) is not viable, since the cosmological upper bound on the lightest sparticle relic abundance is incompatible with the data on the branching ratio of the decay $b \to s + \gamma$.*

Jakobek & Meissner (Bonn) and Olechowski (Warsaw) [116] discussed the problem of the dark energy in the Universe in models of higher-order gravity, in connection with the fine tuning problem of the cosmological constant.

Roszkowski (Lancaster), Ruiz De Austri (Thessalonki) and collaborators [121] studied the coannihilation of neutralinos with sleptons for both the MSSM and the CMSSM and explored the implications for the dark matter abundance of imposing $SO(10)$ boundary conditions on softly broken MSSM [101].

(iii) **Cosmological phase transitions**

Ioannina: The scalar field space of SUSY models can have directions along which the potential becomes unbounded, or local minima deeper than the standard one with broken charge and/or colour symmetries appear. Gioutsos and Vayonakis [46] examined the usual universal soft-parameters of the MSSM as well as a non-universal case of a brane-world minimal SUGRA model for such unphysical vacuua.

Oxford: Kogan and collaborators [58] performed a variational analysis of the QCD deconfinement transition.

Peloso *(Bonn) and* **Sorbo** *(Meudon/IAP) [122] showed that excessive production of gravitational relics can occur from cosmic strings generated at the phase transition which ends hybrid inflation.*

(iv) **Baryogenesis**

Helsinki: Enqvist and Laine [106] elaborated on the perfect formal analogy which exists between Q-balls, and spherically symmetric solitons in certain atomic non-relativistic Bose-Einstein condensates, and discussed the possibility that some aspects of Q-ball cosmology could be studied in the laboratory.

Trieste: Pascoli, Petcov & **Rodejohann** [74] studied a general class of see-saw models of neutrino mass generation, in which the high energy parameters responsible for leptogenesis appear in low energy observables, and presented some of their generic predictions. Pascoli, Petcov & Yaguna [76] showed that in a large class of SUSY GUT models with see-saw mechanism of neutrino mass generation and quasi-degenerate neutrino mass spectrum, lepton flavor violating (LFV) decays $\mu \to e + \gamma$, $\tau \to \mu + \gamma$, ... are predicted to proceed much faster than the usual rate if the baryon asymmetry is required to be produced through leptogenesis. Boubekeur [8] investigated whether it might be possibile for thermal leptogenesis to occur at a low energy scale.

Boubekeur (SISSA), Davidson, **Peloso** *(Bonn) and* **Sorbo** *(Meudon/IAP) [94] discussed the mechanism of generating the baryon asymmetry of the Universe through $B-L$ violating decay of heavy right handed (s)neutrinos, taking into account constraints from both the rescattering effect and gravitino production.*

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

Bonn: Förste [42] investigated D-Branes in models obtained by marginally deforming the string on an $SU(2)$x manifold. Förste and collaborators [41] addressed the issue of general exact marginal deformations for strings on group (semi-simple, compact) manifolds.

Lee and collaborators [12] explored the possibility of solving the flavour problem in a SUSY $SU(5)$ orbifold model with one extra dimension.

Ghilencea and Groot Nibbelink [45] discussed the field theory description of string threshold corrections.

Tasinato and collaborators [125, 128, 124] studied a general class of cosmological solutions of string background equations, furnishing an interpretation of the cosmological properties in terms of negative tension objects. Moreover, they investigated the stability of these backgrounds as well as the problem of particle production .

Ioannina: Leontaris and collaborators [40] considered a particular embedding of seven dimensional self-duality membrane equations in $C^3 \times R$ which breaks G_2 invariance down to SU(3). The world-volume membrane instantons define $SU(3)$ special Lagrangian submanifolds of C^3; solutions of spherical and toroidal topologies were discussed in detail.

Perivolaropoulos [77] considered a Brans-Dicke scalar field, stabilized by a power-law potential and studied oscillations of this field in the case of extra dimensions, where it may be identified with the radion.

Rizos and collaborators [129] undertook a systematic study of Standard Model embeddings in D-Brane configurations of Type I strings, focussing on phenomenological and cosmological issues.

Orsay: Binetruy, Charmousis, **Davis** and Dufaux [5] studied the influence of adding higher-derivative (Gauss-Bonnet) terms in the gravitational action and showed that new classes of solutions appear that localize gravity on the brane. They also studied how such corrections

modify the problem of tuning the cosmological constant to zero, in particular in the context of self-tuning models. Langlois and **Sorbo** [66] considered the production of bulk gravitons from a cosmological bulk.

Fabbrichesi & Piai (SISSA) and **Tasinato** *(Bonn) [39] studied how gravitational effects can modify the physics of neutrinos if these particles are allowed to travel through extra dimensions.*

Falkowski, Olechowski & Pokorski (Warsaw) with Nilles (Bonn) [109] discussed the deconstruction of 5-dimensional SUSY abelian gauge theories compactified on an orbifold, investigating the problem of anomalies, chirality and stability in the decontructed theory.

Groot Nibbelink, Lee & Nilles (Bonn), Olechowski (Warsaw) and Walter [68, 51, 44, 115, 112] continued their investigations of extra-dimensional unified theories with respect to their suitability for consistent cosmological brane-world scenarios. They analyzed the influence of perturbative corrections in higher-dimensional quantum field theory and string theory with respect to the stability of a given classical solution and its potential for driving cosmological evolution, such as inflationary expansion. They observed the mechanism of a dynamical spontaneous localization of bulk fields that may have interesting cosmological consequences.

Kanti (CERN) with **Olasagasti** *& Tamvakis (Ioannina) [119] considered branes embedded in spacetimes of co-dimension $n \geq 1$. They delienated the singularity structure of solutions with a Schwarzschild black hole metric on the brane and also studied solutions of codimension $n > 2$ corresponding to global topological defects with de Sitter slices.*

Kanti (CERN) and Tamvakis (Ioannina) [120] studied a brane with a realistic energy content in a background of a charged AdS black hole which displays a bouncing behaviour with a smooth transition from a contracting to an expanding phase.

(vi) **Cosmological constraints**

Oxford: Boehm, Fayet and Schaeffer [132] studied the bounds set by considerations of structure formation on the possible interactions of dark matter particles with photons. Sarkar [82] reviewed cosmological constraints on massive neutrinos. Fields and Sarkar [52] and Sarkar [82] reviewed primordial nucleosynthesis in the light of new observations of light element abundances and CMB anisotropies and discussed the constraints set on new physics.

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▷ A.2 Joint Publications and Patents

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[95] W. Buchmuller, **P. Di Bari** (Barcelona) and M. Plumacher (CERN), "A bound on neutrino masses from baryogenesis," Phys. Lett. B **547** (2002) 128 [arXiv:hep-ph/0209301].

[96] W. Buchmuller, **P. Di Bari** (Barcelona) and M. Plumacher (CERN), "The neutrino mass window for baryogenesis," arXiv:hep-ph/0302092.

[97] J. M. Cline (CERN), P. Crotty (Annecy) and J. Lesgourgues (Annecy), "Does the small CMB quadrupole moment suggest new physics?," arXiv:astro-ph/0304558.

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[99] T. Damour, I. I. Kogan (Oxford) and **A. Papazoglou** (Bonn), "Non-linear bigravity and cosmic acceleration," Phys. Rev. D **66** (2002) 104025 [arXiv:hep-th/0206044].

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▷ A.2.1 Other Publications by Young Researchers (with non-network collaborators)

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[124] C. P. Burgess, F. Quevedo, S. J. Rey, **G. Tasinato** (Bonn) and I. Zavala, "Cosmological spacetimes from negative tension brane backgrounds," JHEP **0210** (2002) 028 [arXiv:hep-th/0207104].

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[127] **M. Postma** (ICTP) and A. Mazumdar, "Resonant decay of flat directions: Applications to curvaton scenarios, Affleck-Dine baryogenesis, and leptogenesis from a sneutrino condensate," arXiv:hep-ph/0304246.

[128] F. Quevedo, **G. Tasinato** (Bonn) and I. Zavala, "S-branes, negative tension branes and cosmology," arXiv:hep-th/0211031.

▷ A.2.2 Joint Publications with other RTN Networks

[129] I. Antoniadis (CERN), E. Kiritsis (Crete), J. Rizos (Ioannina) and T.N. Tomaras (Crete), "D-branes and the Standard Model," Nucl. Phys. **B660** (2003) 81 [arXiv:hep-th/0210263]. With RTNs HPRN-CT-2000-00148 and HPRN-CT-2000-00131

[130] A. Blanchard (Toulouse), M. Douspis (Oxford), M. Rowan-Robinson and S. Sarkar (Oxford), "An alternative to the cosmological 'concordance model'," arXiv:astro-ph/0304237. With RTN HPRN-CT-2000-00124

[131] C. Boehm and P. Fayet (ENS Paris), "Scalar dark matter candidates," arXiv:hep-ph/0305261.
With RTN HPRN-CT-2000-00148.

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

[133] P. Brax (Saclay) and Z. Lalak (Warsaw), "Brane World Supersymmetry, Detuning, Flipping and Orbifolding", Acta Phys. Polon. B **33** (2002) 2399 [arXiv:hep-th/0207102].
With RTN HPRN-CT-2000-00148.

[134] P. Brax, A. Falkowski and Z. Lalak, arXiv:hep-th/0303167.
With RTN HPRN-CT-2000-00148.

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

[136] A. Brignole (Padua), J. A. Casas, J. R. Espinosa and I. Navarro (Madrid), "Low-scale supersymmetry breaking: Effective description, electroweak breaking and phenomenology," arXiv:hep-ph/0301121.
With RTN 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 where available, 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 mid-term review meeting of the network "Supersymmetry and the Early Universe" was held at Oxford, 25–27 Sep 2002 [`http://hermes.physics.ox.ac.uk/users/SubirSarkar/eunet`] *This attracted 55 participants from the network and 12 others. As listed below, many young researchers, gave talks and there were also review lectures given by senior members of the network. The mid-term review of the network was held on the last day by Dr R. Monk (Brussels)*

and Prof A. Masiero (Padova).
Speakers: **S. Davis** (Orsay), **K. Dimopoulos** (Lancaster), J. Lesgourgues (Annecy), M. Masip (Granada), A. Melchiorri (Oxford), R. Matyszkiewicz (Warsaw), **I. Olasagasti** (Ioannina), **C. Pallis**, M. Sloth, **L. Sorbo** (Meudon/IAP), F. Rota (UA Barcelona), S. Willison (KCL)
Lecturers: K. Enqvist (Helsinki), H.P. Nilles (Bonn), M. Quiros (Madrid), J. Silk (Oxford)

The following international conference was organised *jointly* with our sister network *'Physics Across the Present Energy Frontier'* (HPRN-CT-2000-00148):
6^{th} European Meeting "From the Planck Scale to the Weak Scale," Madrid, 26–31 May 2003

[`http://makoki.iem.csic.es/ planck03/`]
This attracted about 180 participants from the 2 networks and from other institutions in Europe and USA. As listed below, many network members, in particular young researchers, gave talks. The annual business meeting of the network was held on the last day of the conference.
- Organizing Committee (Madrid): A. Casas, J.R. Espinosa, J.M. Moreno and M. Quirós
- Speakers: P. Binétruy (Orsay), L. Boubekeur (SISSA), **P. Bucci (Warsaw)**, **P. Di Bari (Barcelona)**, **K. Dimopoulos (Lancaster)**, E. Dudas (Orsay), H. Dreiner (Bonn), A. Falkowski (Warsaw), A. Faraggi (Oxford), F. Ferrer (Oxford), A. Ibarra (CERN), Z. Lalak (Warsaw), D. Lyth (Lancaster), H.M. Lee (Bonn), H-P. Nilles (Bonn), A. Pomarol (Barcelona), **A. Papazoglou (Bonn)**, S. Pokorski (Warsaw), A. Pomarol (Barcelona), **M. Postma (Trieste)**, G.G. Ross (Oxford/CERN), L. Roszkowski (Lancaster), S. Sarkar (Oxford), G. Senjanovic (Trieste), **L. Sorbo (Annecy)**, **R. Sturani (Helsinki)**, **G. Tasinato (Bonn)**.

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). The 5th such meeting was held at Annecy, 29 Oct 2002: "Journee des Lacs Alpins de Cosmologie" [`http://wwwlapp.in2p3.fr/ lesgourgues/JLAC/jlac.html`]

Some of the many other meetings which network members helped to organise and/or were invited to address were:

• "Workshop on Trends in Neutrino Physics," Argonne, 12–16 May 2003
- Plenary Speaker: A. Casas (Madrid)

• "First International Conference on String phenomenology," Oxford, 6–11 Jul 2002
- IAC: J. Ellis (CERN), N. Mavromatos (KCL), H.P. Nilles (Bonn), S. Pokorski (Warsaw)
- Organising Committee: A. Faraggi (Oxford), **M. Plumacher** (Oxford), G. Ross (Oxford)
- Plenary Speakers: P. Binetruy (Orsay), J. Ellis (CERN), P. Kanti (CERN), Z. Lalak (Warsaw), N. Mavromatos (KCL), C. Munoz (UA Barcelona), H.P. Nilles (Bonn) S. Sarkar (Oxford)
Speakers: D. Chung (CERN), **N. Irges** (Madrid), A. Mazumdar (ICTP), **L. Sorbo** (Meudon/IAP)

• "Time and Matter: An Intern. Colloquium on the Science of Time," Venice, 11–17 Aug 2002
- Plenary Speaker: J. García-Bellido (Madrid)

• "CERN School of Physics," Pylos, Aug-Sep 2002
- Organizing Committee: K. Tamvakis (Ioannina)

• COSMO-02: International Workshop on Particle Physics and the Early Universe, Chicago, 18–21 Sep 2002
- IAC: D. Lyth & L. Roszkowski (Lancaster)
- Plenary Speakers: D. Lyth (Lancaster), M. Quiros (Madrid), L. Roszkowski (Lancaster), G. Sigl (Paris)
- Speakers: P. Crotty (Annecy), **P. Di Bari** (Barcelona), **K. Dimopoulos** (Lancaster), F. Ferrer (Oxford), S. Groot-Nibbelink (Bonn)

• International Workshop on Identification of Dark Matter, York, Sep 2002
- Plenary Speaker: P. Ullio (SISSA)

• "First International Workshop on Frontier Science," 6–11 Oct 2002, Frascati
- Plenary speaker: J. García-Bellido (Madrid)

• "International Conference on Neutrinos and Implications for Physics Beyond the Standard Theory," 11–13 Oct 2002, New York
- Invited speaker: S.T. Petcov (SISSA)

• International Workshop on Neutrinoless Double Beta Decay, Gran Sasso, 9–11 Nov 2002
- Speaker: S.T. Petcov (SISSA), **W. Rodejohann** (SISSA)

• International Workshop "The New Cosmology Confronts Observation," Santa Barbara, Nov–Dec 2002
- Speaker: P. Ullio (SISSA)

• VIII Christmas Workshop on Particle Physics, Madrid, Dec 2002
- Organizing Committee (Madrid): A. Casas, J.R. Espinosa, J. García Bellido, J.M. Moreno and M. Quirós.

• Meeting on Astroparticle Physics with Gamma-Ray Telescopes, Padova, Jan 2003
- Invited Speaker: P. Ullio (SISSA)

• International Workshop on Neutrino Oscillations and their Origin, 9–16 Feb 2003, Kanazawa
- Invited Speaker: S.T. Petcov (SISSA)

• International Conference on Neutrinos: Data, Cosmology and the Planck Scale, 3–7 Mar 2003, Santa Barbara
- Invited Speaker: S.T. Petcov (SISSA)

• 10th International Workshop on Neutrino Telescopes, 11–14 Mar 2003, Venice
- Invited Speaker: S.T. Petcov (SISSA)

• Moriond Workshop on Electroweak Interactions, 12–22 Mar 2003, Les Arcs
- Speakers: **M. Postma** (ICTP), S. Profumo (SISSA) & C. Yaguna (SISSA)

• Electroweak Interactions and Unified Theories, Les Arcs, 15–22 Mar 2003
- Speaker: **M. Postma** (ICTP)

• "SUGRA 20: International Conference on 20 Years of SUGRA and search for SUSY and Unification," Boston, 17–20 Mar 2003
- IAC: M. Quirós (Barcelona)

• HEP 2003: Recent Developments in High Energy Physics and Cosmology, Athens, 17–20 Apr 2003
- Plenary Speakers: J. Ellis (CERN), N. Mavromatos (KCL), S. Sarkar (Oxford), I. Rizos (Ioannina), G. Leontaris (Ioannina)

• Workshop on Science with the New Generation of High Energy Gamma-ray Experiments: "Between Astrophysics and Astroparticle Physics," May 2003, Perugia
- Invited Speaker: P. Ullio (SISSA)

B 4.3

Secondments:
M. Plümacher (Oxford) moved to Geneva as a CERN fellow in Oct 2002.
S. Rasanen moved to Oxford as a post-doctoral fellow in Oct 2002.

Study visits:

J.R. Espinosa (Madrid): visit to CERN for 2 weeks (Mar 2003).
G. Leontaris (Ioannina): visit to CERN and Paris (Jul 2002)
A. Nicolis (Madrid): visit to ICTP for 1 week (Apr 2003).
I. Olasagasti (Ioannina): visit to CERN (Nov 2002)
J. Rizos (Ioannina): visit to CERN and Paris (Jul 2002)

▷ 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 all remaining post-doctoral positions in the network were filled in 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), Dr Antonios Papzoglou (1/10/02–30/06/03), Dr Gianmassimo Tasinato (1/11/02–31/03/03)

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 (1/10/01–30/9/02)**, Dr Alberto Nicolis (1/1/03–31/12/04)*
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 (1/10/01–30/9/02)
Annecy: Dr Lorenzo Sorbo (1/10/02–30/9/03)

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 (01/10/01–30/09/03)

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

Young Researchers Financed by the Contract						
	Deliverable (in Person-Months)			Financed till 6/03 (in Person-Months)		
Participant	Pre-doc	Post-doc	Total	Pre-doc	Post-doc	Total
1. UOXF.DR	0	48	48	0	44	44
2. DPUB	0	24	24	0	38	38
3. CERN	0	0	0	0	0	0
4. UHEL	0	24	24	0	20	20
5. U.IOANNINA	0	48	48	0	38	38
6. CSIC	0	48	48	0	(12)** +5	(12)** + 5
7. LPT	0	48	48	0	41	41
8. SISSA	0	72	72	0	32	32
9. UW	0	24	24	0	20	20
Totals	0	336	336	0	238	238

** *This refers to the appointment of Irges (Madrid) which was subsequently questioned as he was aged over 35 at the time of appointment. We have not counted this in the totals.*

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, Nicolis, 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 new collaborations have been formed between astrophysicists and particle physicists in the network (e.g.).

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 made appointments in Autumn 2001 (in particular Greece and Poland) faced financial difficulties, since their host institutions were unwilling to provide support in advance for the appointed young researchers. We appreciate the effort made by Brussels to avoid such a situation in future by asking for projections of estimated spending for the coming year.

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 has been filled in by the 2 young researchers named below whose contracts terminated during this reporting period, 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

PART D - SKETCHES OF THE YOUNG RESEARCHERS

Antonios Papazoglou received his PhD from Oxford, UK (Sep 2001), with a thesis on *"Brane-World Multigravity"*. He studied a class of brane-world models with anomalously light Kaluza-Klein states, which induce large scale modifications of gravity [1, 3]. He also studied the propagation properties of massive gravitons in (A)dS backgrounds and showed that the van Dam-Veltman-Zakharov no-go theorem is inapplicable in these cases [2]. In Oct 2001, he received the Hodge Fellowship in IHES, Bures-sur-Yvette, France, and studied the cosmology of bigravity, finding general classes of accelerating solutions [4]. From Oct 2002 he has been a network Fellow in Bonn, Germany. There, he studied the question of spherically symmetric spacetimes in massive gravity [5] and is working on issues of self-tuning of the cosmological constant, deconstruction and gauge symmetry breaking in orbifold theories.

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[1] I. I. Kogan, S. Mouslopoulos, **A. Papazoglou**, G. G. Ross and J. Santiago, Nucl. Phys. B **584** (2000) 313 [arXiv:hep-ph/9912552].

[2] I. I. Kogan, S. Mouslopoulos and **A. Papazoglou**, Phys. Lett. B **503** (2001) 173 [arXiv:hep-th/0011138].

[3] I. I. Kogan, S. Mouslopoulos, **A. Papazoglou** and G. G. Ross, Phys. Rev. D **64** (2001) 124014 [arXiv:hep-th/0107086].

[4] T. Damour, I. I. Kogan and **A. Papazoglou**, Phys. Rev. D **66** (2002) 104025 [arXiv:hep-th/0206044].

[5] T. Damour, I. I. Kogan and **A. Papazoglou**, Phys. Rev. D **67** (2003) 064009 [arXiv:hep-th/0212155].

Gianmassimo Tasinato received his PhD in Sissa, Trieste, under the supervision of M. Fabbrichesi and A. Masiero, with the thesis "Global properties of higher dimensional models and their cosmological imlications". During his PhD, he started on working on inflationary model building [1], and on particle physics and cosmological models based on extra-dimensions [2, 3]. Subsequently, he focussed his research on cosmological models obtained from low-energy string theory, in particular trying to understand how the global properties of higher dimensional backgrounds can affect four dimensional cosmology [4]. As a new network fellow at Bonn, he continues this research with the study of the properties of higher dimensional cosmological

solutions of supergravity [5], and parallely he is working on the self tuning approach to the cosmological constant problem.

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Outreach activities

Talks to general audiencies:

- *The origin of the Universe*: talk given by A. Casas (Madrid) at the "Vive la Ciencia" and "Semana de la Ciencia" events in Córdoba, León, Madrid and Zaragoza.
- *The Standard Model of Particle Physics*: talk given by M. Quirós at the Madrid Science Museum, 24 Oct 2002.
- R. Matyszkiewicz and K. Meissner gave popular talks on string theory and extra-dimensions for high school students in Warsaw.

K. Enqvist (Helsinki) published a popular book on cosmology in Finnish ("Kosmoksen hahmo") in Apr 2003.
S. Sarkar (Oxford) wrote a popular article "Is the end in sight for ultrahigh energy cosmic rays" for Physics World [84] and gave several talks to schools.