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 Team which did the work. Collaborative work by members of different teams is *emphasised* and such publications are listed separately (A.2). Additional publications by the **young researchers** of the network are also listed (A.2.1), as well as joint publications with other related networks (A.2.2) and all relevant publications by the network teams (A.2.3).

(i) **Inflation**

Bonn: Kim and Lee [113] provided a paradigm for transition between an inflationary period and a period when the self-tuning mechanism is operative.

Helsinki: Enqvist and collaborators derived a second-order formalism for non-gaussianities in hybrid inflation [86] and studied reheating through the decay of a scalar condensate [81], in particular from a MSSM flat direction [84].

Trieste (SISSA/ICTP): Mazumdar & **Postma** [22] presented a gauge invariant formalism for the evolution of density perturbations in the inhomogeneous reheating scenario and **Postma** discussed the phenomenological constraints [25]. **Postma** showed that the bound on the inflationary Hubble scale in the curvaton scenario may be evaded if the curvaton mass increases significantly in the post-inflationary epoch [26].

Lazarides and **de Austri** *(Thessaloniki) and* **Dimopoulos** *and Lyth (Lancaster) studied the dynamics of the curvaton evolution before and after inflation, taking into account the supergravity corrections as well as thermal effects on the curvaton potential [4].*

Crotty and Lesgourgues (Annecy) with Garcia-Bellido (Madrid) obtained stringent bounds on the possible isocurvature contributions to the primordial fluctuations using recent cosmic microwave background and large scale structure data [3].

(ii) **Dark matter**

Bonn: Nilles proposed a new candidate for 'quintessence' based on the 'model-independent axion' of heterotic string theory [138].

Geneva: Ellis and collaborators pursued studies of supersymmetric cold dark matter and its experimental detection [79], also investigating the case of gravitino dark matter [80].

Ioannina/Thessaloniki: Vergados considered dark matter detection through the study of nuclear transitions to excited states [162].

Madrid/Barcelona/Granada: Massó and collaborators proposed a pseudo-Goldstone boson as a candidate for cold dark matter [130].

Orsay/Paris/Annecy: Binetruy and collaborators [48] investigated direct and indirect detection of dark matter in heterotic orbifold models.

Oxford/Lancaster: Sarkar and collaborators made a detailed study of the *gamma*-ray annihilation signal, finding that the dwarf spheroidals present the best targets [87].

Trieste (SISSA/ICTP): Profumo and Ullio investigated the possible role of quintessence in enhancing the relic cold dark matter density[143] and emphasised the importance of antimatter searches for indirect detection [145]. Ullio and collaborators performed a detailed comparison of direct versus indirect detection prospects [78].

(iii) **Cosmological phase transitions**

Helsinki: Enqvist and collaborators showed that MSSM flat directions can account for the seed magnetic fields in the early Universe by breaking conformal invariance [83].

Jeannerot (Trieste - SISSA) and Rocher (Paris) found that cosmic string formation is inevitable within supersymmetric grand unified theories, assuming standardhybrid inflation and considering all models that have successful baryogenesis [10].

(iv) **Baryogenesis**

Geneva: Giudice and collaborators studied thermal effects in leptogenesis [33] and proposed a new mechanism for leptogenesis in supersymmetric theories [69].

Ioannina/Thessaloniki: Dent, Lazarides and **Ruiz de Austri** studied a non-thermal leptogenesis scenario in which the inflaton decays directly into light particles [17].

Madrid/Barcelona/Granada: Gavela and collaborators [56] established a general relationship between the high-energy parameters and the low-energy observables in the seesaw model of heavy and light Majorana neutrinos and discussed leptogenesis in this framework.

Trieste (SISSA/ICTP): **Rodejohann** analysed the consequences for leptogenesis in seesaw models with hierarchical mass matrices [29] and also considered the contribution of novel diagrams contributing to the decay asymmetry in type II models [30].

Boubekeur (Lancaster), Hambye (Oxford) and Senjanović (Trieste - ICTP) demonstrated the possibility of leptogenesis at low scales using soft supersymmetry breaking terms [1].

Buchmüller, **Di Bari** *(Barcelona) and Plümacher (CERN) presented an analytical description of thermal leptogenesis [2].*

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

Bonn: Nilles, Papazoglou and **Tasinato** studied brane-world models which try to realise the self-tuning mechanism of the cosmological constant [24] and Lee [121] discussed the associated fine-tuning problem. **Tasinato** and collaborators studied the properties of new examples of codimension-2 brane world models [13, 21] and constructed models that smoothly connect from a contracting to an expanding universe [15]; they also , presented new time dependent solutions for low energy string systems that are free of cosmological singularities [31].

Geneva: Veneziano, Giovannini and collaborators computed the spectrum of scalar and tensor perturbations in non-singular bouncing cosmologies, deriving observational consequences of pre-big bang scenarios [93]. Veneziano considered a description of the early universe in terms of a dense gas of string states lying on the correspondence curve between string and black holes [160]. Ellis and collaborators proposed supersymmetric models of space-time foam which can account for the observed dark energy [9]. These models can violate the equivalence principle [8] and evade the constraints imposed by the synchrotron radiation from the Crab Nebula [7, 6].

Helsinki: Enqvist and coolaborators argued that a brane world with a warped, infinite extra dimension allows for the inflaton to decay into the bulk so that all matter and CMB density perturbations could have their origin in the decay of a MSSM flat direction rather than the inflaton [85]. Keski-Vakkuri and Sloth discussed how holographic bounds can be applied to the quantum fluctuations of the inflaton and proposed that the entanglement entropy is a natural measure of the entropy of the quantum perturbations [112].

Ioannina/Thessalonki: Perivolaropoulos studied the core structure of global vortices on topologically deformed brane world models [141].

Madrid/Barcelona: **Nicolis** and Rattazzi [23] proved the stability of the Dvali-Gabadadze-Porrati model by the method of the boundary effective action. Quirós and colaborators studied the issue of radion stabilization within five-dimensional supersymmetric theories compactified on the orbifold S^1/Z_2 [34] and the propagation of fermions in the bulk [35].

De Carlos and Moreno [70, 71] considered localization of gravity on string like topological defect within a 6-dimensional space-time.

Warsaw: Meissner and Olechowski found general warped solutions of the string inspired dilaton gravity system with bulk cosmological constant [133]. **Bucci** and collaborators demonstrated the possibility of stabilization of the scalar sector, including the radion, in the gauge model with one universal extra dimension [14]. Lalak and Matyszkiewicz analyzed the breakdown of global supersymmetry by a non-vanishing expectation value of the fifth component of the graviphoton on warped S^1/Z_2 orbifolds [116].

Groot Nibbelink, Hillenbach, Lee, Nilles, Walter and Zucker (Bonn) and Olechowski (Warsaw) continued their investigations of extra-dimensional unified theories with respect to their suitability for consistent cosmological brane-world scenarios [123, 122, 136].

Kanti (Geneva), with Tamvakis and **Olasagasti** *(Ioannina) studied further the posibility of obtaining localized black hole solutions in the framework of Randall-Sundrum brane world models [11].*

Rizos (Ioannina), with Nooij and Faraggi (Oxford) classified the $\mathcal{Z}_2 \times \mathcal{Z}_2$ orbifold with symmetric shifts on six dimensional compactified internal manifolds and presented a class of three generation $SO(10)$ models [36].

(vi) **Cosmological constraints**

Ioannina/Thessaloniki: Perivolaropoulos and Nesseris used the latest data on the SN Ia Hubble diagram to find the best-fit cosmological model [134].

Madrid/Barcelona: Grifols and Massó obtained a constraint on long range forces that could be induced by lepton chargesby studying the propagation of neutrinos produced in the Sun [94].

Oxford/Lancaster: Sarkar reviewed Big Bang nucleosynthesis and the constraints it sets on new physics [5].

▷ A.2 Joint Publications and Patents

Electronic versions of nearly all publications listed below are available on the Network's webpage:
`http://www-thphys.physics.ox.ac.uk/users/SubirSarkar/eunetwork/publications/2003-04.html`

[1] L. Boubekeur (Lancaster), T. Hambye (Oxford) and G. Senjanovic (Trieste - ICTP), "Low-scale leptogenesis and soft supersymmetry breaking," arXiv:hep-ph/0404038.

[2] W. Buchmüller, **P. Di Bari** (Barcelona) and M. Plümacher (Geneva), "Leptogenesis for pedestrians," [arXiv:hep-ph/0401240].

[3] P. Crotty (Annecy), J. García-Bellido (Madrid), J. Lesgourgues (Annecy) and A. Riazuelo, "Bounds on isocurvature perturbations from CMB and LSS data," Phys. Rev. Lett. **91** (2003) 171301 [arXiv:astro-ph/0306286].

[4] **K. Dimopoulos** (Lancaster/Oxford), G. Lazarides (Thessaloniki), D. Lyth (Lancaster) and **R. Ruiz de Austri** (Thessaloniki) : "Curvaton Dynamics," Phys. Rev. D **68** (2003) 123515 [arXiv:hep-ph/0308015].

[5] S. Eidelman *et al.* [Particle Data Group Collaboration], "Review of particle physics," Phys. Lett. B **592**, 1 (2004). [includes as authors: J. March-Russell (Geneva), S. Sarkar (Oxford)]

[6] J.R. Ellis (Geneva), N.E. Mavromatos (KC London) and A.S. Sakharov, "Synchrotron radiation from the Crab Nebula discriminates between models of space-time foam," Astropart. Phys. **20** (2004) 669 [arXiv:astro-ph/0308403].

[7] J.R. Ellis (Geneva), N.E. Mavromatos (KC London), D.V. Nanopoulos and A.S. Sakharov (Geneva), "Synchrotron radiation and quantum gravity," arXiv:astro-ph/0309144.

[8] J.R. Ellis (Geneva), N.E. Mavromatos (KC London), D.V. Nanopoulos and A.S. Sakharov (Geneva), "Space-time foam may violate the principle of equivalence," arXiv:gr-qc/0312044.

[9] J.R. Ellis (Geneva), N.E. Mavromatos (KC London) and M. Westmuckett (KC London), "A supersymmetric D-brane model of space-time foam," Phys. Rev. D **70**, 044036 (2004) [arXiv:gr-qc/0405066].

[10] R. Jeannerot (Trieste - SISSA), J. Rocher (Paris - IAP) and M. Sakellariadou, "How generic is cosmic string formation in SUSY GUTs," Phys. Rev. D **68** (2003) 103514 [arXiv:hep-ph/0308134].

[11] P. Kanti (Geneva), **I. Olasagasti** (Ioannina) and K. Tamvakis (Ioannina), "Quest for localized 4-D black holes in brane worlds. II: Removing the bulk singularities," Phys. Rev. D **68**, 124001 (2003) [arXiv:hep-th/0307201].

[12] J. Lesgourgues (Geneva) and **L. Sorbo** (Annecy) , "Goldberger-Wise variations: Stabilizing brane models with a bulk scalar," Phys. Rev. D **69** (2004) 084010 [arXiv:hep-th/0310007].

▷ A.2.1 Additional Publications by the Young Researchers of the Network

[13] Y. Aghababaie, C.P. Burgess, J.M. Cline, H. Firouzjahi, S.L. Parameswaran, F. Quevedo, **G. Tasinato** (Bonn) and I. Zavala, "Warped brane worlds in six dimensional supergravity," JHEP **0309** (2003) 037 [arXiv:hep-th/0308064].

[14] **P. Bucci** (Warsaw), B. Grzadkowski, Z. Lalak and R. Matyszkiewicz, "Electroweak symmetry breaking and radion stabilization in universal extra dimensions," JHEP **0404** (2004) 067 [arXiv:hep-ph/0403012].

[15] C.P. Burgess, F. Quevedo, R. Rabadan, **G. Tasinato** (Bonn) and I. Zavala, "On bouncing brane worlds, S-branes and branonium cosmology," JCAP **0402** (2004) 008 [arXiv:hep-th/0310122].

[16] C. Charmousis, **S.C. Davis** (Orsay) and J.F. Dufaux, "Scalar brane backgrounds in higher order curvature gravity," JHEP **0312**, 029 (2003) [arXiv:hep-th/0309083].

[17] T. Dent, G. Lazarides and **R. Ruiz de Austri** (Thessaloniki), "Leptogenesis through direct inflaton decay to light particles", Phys. Rev. D **69** (2004) 075012 [arxiv: hep-ph/0312033].

[18] **P. Di Bari** (Barcelona), "Leptogenesis and neutrino mixing data," Proc. 2nd International Workshop on Neutrino Oscillations in Venice (NO-VE 2003), p.497

[19] P.H. Frampton, S.T. Petcov and **W. Rodejohann** (SISSA), "On deviations from bimaximal neutrino mixing," Nucl. Phys. B **687**, 31 (2004) [arXiv:hep-ph/0401206].

[20] D. Langlois and **L. Sorbo** (Annecy), "Bulk gravitons from a cosmological brane," Phys. Rev. D **68**, 084006 (2003) [arXiv:hep-th/0306281].

[21] H.M. Lee and **G. Tasinato** (Bonn), "Cosmology of intersecting brane world models in Gauss-Bonnet gravity," JCAP **0404** (2004) 009 [arXiv:hep-th/0401221].

[22] A. Mazumdar and **M. Postma** (Trieste - ICTP), "Evolution of primordial perturbations and a fluctuating decay rate," Phys. Lett. B **573** (2003) 5 [Erratum-ibid. B **585** (2004) 295] [arXiv:astro-ph/0306509].

[23] **A. Nicolis** (Madrid) and R. Rattazzi, "Classical and quantum consistency of the DGP model," [arXiv:hep-th/0404159].

[24] H.P. Nilles, **A. Papazoglou** (Bonn) and **G. Tasinato** (Bonn), "Selftuning and its footprints," Nucl. Phys. B **677** (2004) 405 [arXiv:hep-th/0309042].

[25] **M. Postma** (Trieste - ICTP), "Inhomogeneous reheating scenario with low scale inflation and/or MSSM flat directions," JCAP **0403** (2004) 006 [arXiv:astro-ph/0311563].

[26] **M. Postma** (Trieste - ICTP),, "Curvaton scenario with low scale inflation revisited," JCAP **0405** (2004) 002 arXiv:astro-ph/0403213.

[27] **W. Rodejohann** (Trieste - SISSA), "Neutrino mass matrices leaving no trace," Phys. Lett. B **579**, 127 (2004) [arXiv:hep-ph/0308119].

[28] **W. Rodejohann** (Trieste - SISSA), "A parametrization for the neutrino mixing matrix," Phys. Rev. D **69**, 033005 (2004) [arXiv:hep-ph/0309249].

[29] **W. Rodejohann** (Trieste - SISSA), "Hierarchical matrices in the see-saw mechanism, large neutrino mixing and leptogenesis," Eur. Phys. J. C **32**, 235 (2004) [arXiv:hep-ph/0311142].

[30] **W. Rodejohann** (Trieste - SISSA), "Type II see-saw mechanism, deviations from bimaximal neutrino mixing and leptogenesis," arXiv:hep-ph/0403236.

[31] **G. Tasinato** (Bonn), I. Zavala, C.P. Burgess and F. Quevedo, "Regular S-brane backgrounds," JHEP **0404** (2004) 038 [arXiv:hep-th/0403156].

▷ A.2.2 Joint Publications with other RTN Networks

[32] C. Boehm (Oxford), P. Fayet (ENS Paris) and J. Silk, "Light and heavy dark matter particles," Phys. Rev. D **69** (2004) 101302 [arXiv:hep-ph/0311143].
With RTN HPRN-CT-2000-00148

[33] G. F. Giudice (Geneva), A. Notari, M. Raidal, A. Riotto (Padova) and A. Strumia, "Towards a complete theory of thermal leptogenesis in the SM and MSSM," Nucl. Phys. B **685** (2004) 89 [arXiv:hep-ph/0310123].
With RTN HPRN-CT-2000-00148

[34] G. von Gersdorff, M. Quirós (Madrid) and A. Riotto (Padova), "Scherk-Schwarz supersymmetry breaking with radion stabilization," Nucl. Phys. B **689** (2004) 76 [arXiv:hep-th/0310190].
With RTN HPRN-CT-2000-00148.

[35] G. von Gersdorff, L. Pilo (Padova), M. Quirós (Barcelona), A. Riotto (Padova) and V. Sanz, "Fermions and supersymmetry breaking in the interval," [arXiv:hep-th/0404091].
With RTN HPRN-CT-2000-00148.

[36] A.E. Faraggi (Oxford), C. Kounnas (ENS Paris), S.E.M. Nooij (Oxford) and J. Rizos (Ioannina), "Classification of the chiral Z2XZ2 fermionic models in the heterotic superstring", Nucl. Phys. B **695** (2004) 41 [arXiv:hep-th/0403058].
With RTN HPRN-CT-2000-00148.

[37] J. Lesgourgues (Annecy), S. Pastor (Valencia) and L. Perotto, "Probing neutrino masses with future galaxy redshift surveys," Phys. Rev. D **70**, 045016 (2004) [arXiv:hep-ph/0403296].
With RTN HPRN-CT-2000-00148.

[38] N.E. Mavromatos (KC London) and J. Papavassiliou (Valencia), "Super heavy dark matter anisotropies from D-particles in the early Int. J. Mod. Phys. A **19** (2004) 2355 [arXiv:hep-th/0307028].
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▷ A.2.3 Other relevant Publications by Team Members

[39] E. K. Akhmedov, M. Frigerio and A. Y. Smirnov, "Probing the seesaw mechanism with neutrino data and leptogenesis," JHEP **0309** (2003) 021 [arXiv:hep-ph/0305322].

[40] C.S. Aulakh, B. Bajc, A. Melfo, G. Senjanovic and F. Vissani, "The minimal supersymmetric grand unified theory," Phys. Lett. B **588** (2004) 196 [arXiv:hep-ph/0306242].

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[42] J.F. Beacom, N.F. Bell, D. Hooper, J.G. Learned, S. Pakvasa and T.J. Weiler, "Pseudo-Dirac neutrinos, a challenge for neutrino telescopes," Phys. Rev. Lett. **92** (2004) 011101 [arXiv:hep-ph/0307151].

[43] J.F. Beacom, N.F. Bell, D. Hooper, S. Pakvasa and T.J. Weiler, "Measuring flavor ratios of high-energy astrophysical neutrinos," Phys. Rev. D **68** (2003) 093005 [arXiv:hep-ph/0307025].

[44] J.F. Beacom, N.F. Bell, D. Hooper, S. Pakvasa and T.J. Weiler, "Sensitivity to Theta(13) and delta in the decaying astrophysical neutrino scenario," Phys. Rev. D **69** (2004) 017303 [arXiv:hep-ph/0309267].

[45] G. Bertone, D. Hooper and J. Silk, "Particle dark matter: Evidence, candidates and constraints," arXiv:hep-ph/0404175.

[46] P. Binetruy, M. Bucher and C. Carvalho, "Models for the brane-bulk interaction: Toward understanding braneworld Phys. Rev. D **70** (2004) 043509 [arXiv:hep-th/0403154].

[47] P. Binetruy, G. Dvali, R. Kallosh and A. Van Proeyen, "Fayet-Iliopoulos terms in supergravity and cosmology," Class. Quant. Grav. **21**, 3137 (2004) [arXiv:hep-th/0402046].

[48] P. Binetruy, Y. Mambrini and E. Nezri, "Direct and indirect detection of dark matter in heterotic orbifold models," arXiv:hep-ph/0312155.

[49] M. Blau, M. Borunda, M. O'Loughlin and G. Papadopoulos, "Penrose limits and spacetime singularities," Class. Quant. Grav. **21** (2004) L43 [arXiv:hep-th/0312029].

[50] M. Blau, M. Borunda, M. O'Loughlin and G. Papadopoulos, "The universality of Penrose limits near space-time singularities," JHEP **0407** (2004) 068 [arXiv:hep-th/0403252].

[51] C. Boehm, D. Hooper, J. Silk and M. Casse, "MeV dark matter: Has it been detected?," Phys. Rev. Lett. **92** (2004) 101301 [arXiv:astro-ph/0309686].

[52] C. Boehm, H. Mathis, J. Devriendt and J. Silk, "WIMP matter power spectra and small scale power generation," arXiv:astro-ph/0309652.

[53] M. Bojowald and H. A. Morales-Tecotl, "Cosmological applications of loop quantum gravity," Lect. Notes Phys. **646** (2004) 421 [arXiv:gr-qc/0306008].

[54] M. Borunda, "On string gas cosmology at finite temperature," arXiv:hep-th/0310032.

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[56] A. Broncano, M.B. Gavela and E. Jenkins, 'Neutrino physics in the seesaw model," Nucl. Phys. B **672** (2003) 163 [arXiv:hep-ph/0307058.]

[57] A. Cafarella, C. Coriano and A.E. Faraggi, "Ultra high energy cosmic rays and air shower simulations: A top-bottom view," arXiv:hep-ph/0306236.

[58] A. Cafarella, C. Coriano and A.E. Faraggi, "Large scale air shower simulations and the search for new physics at AUGER," Int. J. Mod. Phys. A **19** (2004) 3729 [arXiv:hep-ph/0308169].

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[61] M. Casse, J. Paul, G. Bertone and G. Sigl, "Gamma rays from the Galactic bulge and large extra dimensions," Phys. Rev. Lett. **92**, 111102 (2004) [arXiv:hep-ph/0309173].

[62] C. Charmousis and J.F. Dufaux, "Gauss-Bonnet gravity renders negative tension branewolds unstable," arXiv:hep-th/0311267.

[63] C. Charmousis and U. Ellwanger, "Radion and moduli stabilization from induced brane actions in JHEP **0402**, 058 (2004) [arXiv:hep-th/0402019].

[64] K.Y. Choi, Y. Kajiyama, H.M. Lee and J. Kubo, "Double suppression of FCNCs in supersymmetric models," arXiv:hep-ph/0402026.

[65] K.Y. Choi and H.M. Lee, "Softness of brane-localized supersymmetry breaking on orbifolds," Phys. Lett. B **575** (2003) 309 [arXiv:hep-th/0306232].

[66] E.J. Chun, K. Dimopoulos and D. Lyth, "Curvaton and QCD axion in supersymmetric theories," arXiv:hep-ph/0402059.

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[73] A. D. Dolgov, "Problems of vacuum energy and dark energy," arXiv:hep-ph/0405089.

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[81] K. Enqvist and J. Hogdahl, "Scalar condensate decay in a fermionic heat bath in the early universe," arXiv:hep-ph/0405299.

[82] K. Enqvist, A. Jokinen and A. Mazumdar, "Dynamics of MSSM flat directions consisting of multiple scalar fields," JCAP **0401**, 008 (2004) [arXiv:hep-ph/0311336].

[83] K. Enqvist, A. Jokinen and A. Mazumdar, arXiv:hep-ph/0404269.

[84] K. Enqvist, S. Kasuya and A. Mazumdar, "MSSM Higgses as the source of reheating and all matter," Phys. Rev. Lett. **93** (2004) 061301 [arXiv:hep-ph/0311224].

[85] K. Enqvist, A. Mazumdar and A. Perez-Lorenzana, "Dumping inflaton energy density out of this world," arXiv:hep-th/0403044.

[86] K. Enqvist and A. Vaihkonen, "Non-Gaussian perturbations in hybrid inflation," arXiv:hep-ph/0405103.

[87] N.W. Evans, F. Ferrer and S. Sarkar, "A Travel guide to the dark matter annihilation signal," Phys. Rev. D **69** (2004) 123501 [arXiv:astro-ph/0311145].

[88] N.W. Evans, F. Ferrer and S. Sarkar, "Reply to 'Comment on 'Clustering of ultrahigh energy cosmic rays and their sources' '," Phys. Rev. D **69** (2004) 128302 [arXiv:astro-ph/0403527].

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[90] A.E. Faraggi, "Superstring phenomenology in light of LEP, KamLAND and WMAP," arXiv:hep-ph/0402029.

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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 repeated here).

B 4.2

• The following international conference was organised *jointly* with our sister EU network *'Physics Across the Present Energy Frontier'* (HPRN-CT-2000-00148):
"From the Planck Scale to the Weak Scale," Bad Honnef, 24–28 May 2004

(`http://www.th.physik.uni-bonn.de/nilles/planck04/index.html`)
This attracted about 100 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 during the conference.
- Organizing Committee (Bonn): H.-P. Nilles, **G. Tasinato**

- Speakers: L. Boubekeur (Lancaster), A. Casas (Madrid), T. Dent (Ioannina), H. Dreiner (Bonn), J. Espinosa (Madrid), A. Falkowski (Warsaw), A. Faraggi (Oxford), A. Ibarra (CERN), D. Lyth (Lancaster), J. Moreno (Madrid), **A. Nicolis (Madrid)**, M. Plümacher (Geneva), **M. Postma (Trieste - ICTP)**, M. Quiros (Madrid), G.G. Ross (Oxford/CERN), L. Roszkowski (Lancaster), **W. Rodejohann** (SISSA), S. Sarkar (Oxford), **G. Tasinato (Bonn)**, M. Thormeier (Bonn). K. Turzynski (Warsaw), S. West (Oxford)

• The following international school was also organised by our network:
Second Aegean School on the Early Universe, Syros, 22–30 Sep 2003

(`http://www.physics.ntua.gr/cosmo03/`)
This attracted about 90 participants and the main lecturers included S. Sarkar (Oxford) and K. Tamavakis (Ioannina). Other network members gave short talks as listed below.

- Speakers: **K. Dimopoulos** (Lancaster), T. Dent (Thessaloniki), I. Rizos (Ioannina), G. Leontaris (Ioannina), **R. Ruiz de Austri** (Thessaloniki), **A. Papazoglou**(Bonn), F. Ferrer (Oxford), N. Mavromatos (London), G. Lazarides (Thessaloniki), L. Perivolaropoulos (Ioannina)

• 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 6th such meeting was held at Geneva, 21 Jan 2004 and the 7th meeting at Lausanne, 26 May 2004: "Journee des Lacs Alpins de Cosmologie"
(`http://wwwlapp.in2p3.fr/ lesgourgues/JLAC/jlac.html`)

Some other meetings which network members organised and/or were invited to speak at were:

• "Supersymmetry in the Desert: SUSY 2003", Tucson, 5–10 June 2003
(`http://www.physics.arizona.edu/susy2003/`)
- Invited Speaker: M. Quirós (Madrid)

• First Yamada Symposium and International Conference on "Neutrinos, Dark Matter and Nuclear Physics", Nara, 9–14 Jun 2003
- Invited Speaker: S.T. Petcov (Trieste - SISSA)

• Baryogenesis workshop, Ann Arbor, 9–27 Jun 2003
- Speaker: **P. Di Bari** (Barceolona), **W. Rodejohann** (Trieste - SISSA)

• Euresco Conference "What Comes Beyond the Standard Model?", Portoroz, 12–17 Jul 2003
- Speakers: Martin Sloth (Helsinki), **M. Postma** (Trieste - ICTP)

• International Europhysics Conference on High Energy Physics, Aachen, 17–23 Jul 2003
- Speaker **W. Rodejohann** (Trieste - SISSA)

• SLAC Summer Institute On Particle Physics: "Cosmic Connection To Particle Physics", Stanford, 28 Jul – 8 Aug 2003
(`http://www-conf.slac.stanford.edu/ssi/2003/`)
- Lecturer: J. Ellis (Geneva)

• "Second International Conference on String phenomenology," Durham, 29 Jul – 4 Aug 2003
(`http://www.ippp.dur.ac.uk/SP03/`)
- Organising Committee: A. Faraggi (Oxford)
- Speakers: J. March-Russell (Oxford), H.P. Nilles (Bonn), P. Kanti (CERN), Z. Lalak (Warsaw), N. Mavromatos (London), M. Quiros (Madrid), J. Casas (Madrid), V. Di Clemente (Oxford), M. Borunda (Trieste)

• COSMO-03: International Workshop on Particle Physics and the Early Universe, Ambleside, 25–29 Aug 2003
(`http://www.ippp.dur.ac.uk/cosmo03/`)
- Speakers: H.P. Nilles (Bonn), K. Enqvist (Helsinki), **R. Sturani (Helsinki)**, Martin Sloth (Helsinki), A. Jokinen (Helsinki), J. Valiviita (Helsinki), F. Ferrer (Oxford), D. Langlois (Paris),

• "Conference On Thinking, Observing And Mining The Universe", Sorrento, 22-27 Sep 2003
(`http://www.na.infn.it/congr/Thinking2003/`)
- Invited Speaker: E. Massó (Barcelona)

• "DESY Theory Workshop 2003: GUTS and Branes", Hamburg, 23–26 Sep 2003
(`http://www.desy.de/desy-th/workshop2003/`)
- Invited Speaker: M. Quirós (Madrid)

• "Hierarchy Problems in Four and More Dimensions", ICTP Trieste, 1-4 Oct 2003
(`http://agenda.ictp.trieste.it/agenda/current/fullAgenda.php?ida=a0386`)
- Invited Speaker: M. Quirós (Madrid)

• International Workshop on "Astroparticle & High-Energy Physics", Valencia, 14–18 Oct 2003
(`http://nac15.ific.uv.es/conference/`)
- Invited Speakers: C, Boehm (Oxford), J. García-Bellido (Madrid), E. Massó (Barcelona), S. Sarkar (Oxford)

• 2nd International Workshop on Neutrino Oscillations, Venice, 5–8 Dec 2003
- Invited Speaker: S.T. Petcov (Trieste - SISSA)

• "Dark Matter and Dark Energy", Bad Honnef, 8–11 Dec 2003
(`http://www.th.physik.uni-bonn.de/nilles/darkmatter/`)
-Organising Commettee: H. P. Nilles (Bonn)
-Speakers: P. Binétruy (Orsay), K. Enqvist (Helsinki), D. Hooper (Oxford),**A. Papazoglou** (Bonn), M. Plümacher (Geneva), S. Sarkar (Oxford), **G. Tasinato** (Bonn)

• " IX Christmas Workshop on Particle Physics," Madrid, 15–17 Dec 2003
(`http://gesalerico.ft.uam.es/workshop9/workshop03.html`)
- Organising Committee: A. Casas, J.R. Espinosa, J. García-Bellido, M.B. Gavela, J.M. Moreno and M. Quirós (Madrid)
-Invited speaker: J. Lesgourgues (Annecy)

• "The Third Generation as a Probe for New Physics: Experimental and Technological Approach", IFAE/UAB Barcelona, 18–20 Dec 2003
- Invited Speaker: M. Quirós (Madrid)

• "From Fields to Strings: Circumnavigating Theoretical Physics. A Conference in Tribute to Ian Kogan," Oxford, 8–10 Jan 2004
(`http://http://www-thphys.physics.ox.ac.uk/users/PeterAusting/Conference/`)
- Organisation: S. Sarkar
- Speakers: **A. Papazoglou** (Bonn), S. Randjbar-Daemi (Trieste - ICTP)

• IoP Meeting on Double Beta Decay, Brighton, 28 Jan 2004
- Speaker **W. Rodejohann** (Trieste - SISSA)

• International Workshop on Neutrino Oscillations and their Origin, Tokyo, 11–15 Feb 2004
- Invited Speaker: S.T. Petcov (Trieste - SISSA)

• " XXXII International Meeting on Fundamental Physics", Alicante, 1–5 Mar 2004
(`http://ific.uv.es/imfp04/`)
- Invited Speaker: J. García-Bellido (Madrid)

• " XXXIXth Rencontrés de Moriond: ElectroWeak Interactions and Unified Theories", La Thuile, 21–28 Mar 2004 (`http://moriond.in2p3.fr/EW/2004/`)
- Invited Speakers: **P. Di Bari** (Barcelona), J.R. Espinosa (Madrid)

• "Contents and Structures of the Universe", La Thuile, 28 Mar – 4 Apr 2004
(`http://moriond.in2p3.fr/J04/`)
- Invited Speaker: J. García-Bellido (Madrid), F. Ferrer (Oxford)

B 4.3

Study visits:
W. Rodejohann (SISSA): visit to DESY Hamburg for 1 week (Jun 2003)
G. Leontaris (Ioannina): visit to CERN Geneva (Dec 2003)
J. Rizos (Ioannina): visit to CERN Geneva (Jan 2004)

G. Leontaris (Ioannina): visit to CERN Geneva (Jan 2004)
K. Tamvakis (Ioannina): visit to CERN Geneva (Feb 2004), visit to Oxford (Jan 2004),
P. Di Bari (Barcelona): visit to Madrid (Apr 2004)
J.M. Moreno (Madrid) visit to CERN Geneva (Nov 2003, Feb 2004)
A Nicolis (Madrid): visit to CERN Geneva (Jun, Nov 2003), visit to Trieste (Nov 2003)

▷ B.5 Training

B.5.1

All positions for young researchers have been filled so no vacancies were advertised .

B.5.2

During this year nearly all the remaining training was delivered. An updated 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 (16/2/03–15/11/04)*
Barcelona: Dr Pasquale Di Bari (1/9/02–31/8/04)*

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 (8/10/02–7/10/04)*
ICTP: Dr Marieke Postma (16/9/02–15/9/04)*

9. Warsaw: Dr Patrizia Bucci (01/10/01–30/09/03)

*The appointments marked * extend beyond the nominal end of the network contract on 31 May 2004. Hence we requested an extension of the contract period by 6 months. In the event an extension by only 4 months (until 30 Sep 2004) was granted.*

Young Researchers Financed by the Contract						
	Deliverable (in Person-Months)			Financed till 6/04 (in Person-Months)		
Participant	Pre-doc	Post-doc	Total	Pre-doc	Post-doc	Total
1. UOXF.DR	0	48	48	0	48	48
2. DPUB	0	24	24	0	38	38
3. CERN	0	0	0	0	0	0
4. UHEL	0	24	24	0	24	24
5. U.IOANNINA	0	48	48	0	48	48
6. CSIC	0	48	48	0	(12)** + 38.5	(12)** + 38.5
7. LPT	0	48	48	0	48	48
8. SISSA	0	72	72	0	64.5	64.5
9. UW	0	24	24	0	24	24
Totals	0	336	336	0	333	333

** This refers to the appointment of Irges (Madrid) which was subsequently deemed invalid 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 were 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. xxx).

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 accordance 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 welcome the initiative by Brussels to avoid such situations by asking for projections of estimated spending along with the annual financial statements.

Secondly, some members have moved to different institutions. 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. (This need not mean changing the financial arrangements, for example they could be supported for attending network meetings by their previous host institutions.) Since the EU Framework programme is focussed on promoting mobility, it is surprising that so little flexibility is shown in this regard.

Part C - Summary Reports by Young Researchers

The questionnaire has been filled in by the young researchers named below whose contracts terminated during this reporting period, and sent to Brussels:

1. **Patrizia Bucci**, Italian, 1/10/01–30/09/03, University of Warsaw, Poland
2. **Stephen Davis** (British, 1/09/01–31/8/03, University Paris-Sud Orsay, France
3. **Konstantinos Dimopoulos**, Greek, 1/10/01–30/9/03, University of Lancaster, UK
4. **Itsaso Olasagasti**, Spanish, 1/11/01–1/11/03, University of Ioannina, Greece
5. **Constantinos Pallis**, 1/2/02–31/1/04, SISSA Trieste, Italy
6. **Roberto Ruiz de Austri**, Spanish, 1/11/01–1/11/03, University of Thessaloniki, Greece
7. **Riccardo Sturani**, Italian, 1/10/01–30/9/03, University of Helsinki, Finland

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.

Five key publications:

[1] I. I. Kogan, S. Mouslopoulos, **A. Papazoglou**, G. G. Ross and J. Santiago, "A three three-brane universe: New phenomenology for the new millennium?," Nucl. Phys. B **584** (2000) 313 [arXiv:hep-ph/9912552].

[2] I. I. Kogan, S. Mouslopoulos and **A. Papazoglou**, "The m $\to$ 0 limit for massive graviton in dS(4) and AdS(4): How to circumvent the van Dam-Veltman-Zakharov discontinuity," Phys. Lett. B **503** (2001) 173 [arXiv:hep-th/0011138].

[3] I. I. Kogan, S. Mouslopoulos, **A. Papazoglou** and G. G. Ross, "Multigravity in six dimensions: Generating bounces with flat positive tension branes," Phys. Rev. D **64** (2001) 124014 [arXiv:hep-th/0107086].

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

[5] T. Damour, I. I. Kogan and **A. Papazoglou**, "Spherically symmetric spacetimes in massive gravity," 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.

Five key publications:

[1] L. Boubekeur and **G. Tasinato**, "Universal singlets, supergravity and inflation," Phys. Lett. B **524** (2002) 342 [arXiv:hep-ph/0107322].

[2] M. Fabbrichesi, M. Piai and **G. Tasinato**, "Axion and neutrino physics from anomaly cancellation," Phys. Rev. D **64** (2001) 116006 [arXiv:hep-ph/0108039].

[3] C. Grojean, F. Quevedo, **G. Tasinato** and I. Zavala, "Branes on charged dilatonic backgrounds: Self-tuning, Lorentz violations and cosmology," JHEP **0108** (2001) 005 [arXiv:hep-th/0106120].

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

[5] C. P. Burgess, P. Martineau, F. Quevedo, **G. Tasinato** and I. Zavala C., "Instabilities and particle production in S-brane geometries," JHEP **0303** (2003) 050 [arXiv:hep-th/0301122].

Pasquale Di Bari obtained his Ph.D. from the University of Rome 'La Sapienza' under the supervision of Maurizio Lusignoli with a thesis entitled *Neutrino mixing in the early Universe* [1,2]. Then he spent one year at the University of Melbourne with an INFN fellowship, collaborating with Robert Foot and Ray Volkas. With Robert Foot he studied how the new CMB measurements of the baryon asymmetry were able to improve the constraints on new physics in conjunction with Big Bang nucleosynthesis and primordial nuclear abundances observations [3]. Subsequently he moved to DESY Hamburg with a von Humboldt fellowship. In collaboration wtih Wilfried Buchmuller and Michael Plumacher he studied how from leptogenesis it is possible to put a stringent upper bound on the absolute neutrino mass scale [4, 5].

Five key publications:

[1] **P. Di Bari**, P. Lipari and M. Lusignoli, "The $\nu_\mu \leftrightarrow \nu_s$ interpretation of the atmospheric neutrino data and cosmological constraints", Int. J. Mod. Phys. A **15** (2000) 2289 [arXiv:hep-ph/9907548].

[2] **P. Di Bari**, "Amplification of isocurvature perturbations induced by active-sterile neutrino oscillations", Phys. Lett. B **482** (2000) 150 [arXiv:hep-ph/9911214].

[3] **P. Di Bari** and R. Foot, "Active-sterile neutrino oscillations and BBN + CMBR constraints", Phys. Rev. D **63** (2001) 043008 [arXiv:hep-ph/0008258].

[4] W. Buchmuller, **P. Di Bari** and M. Plumacher, "Cosmic microwave background, matter-antimatter asymmetry and neutrino masses", Nucl. Phys. B **643** (2002) 367 [arXiv:hep-ph/0205349].

[5] W. Büchmuller, **P. Di Bari** and M. Plümacher, *A bound on neutrino masses from baryogenesis*, Phys. Lett. B **547** (2002) 128, hep-ph/0209301.

Alberto Nicolis received his PhD from Scuola Normale Superiore, Pisa, in January 2003, under the supervision of M. Maggiore. During his PhD he participated in several collaborations. With M. Maggiore he analyzed the possibility of detecting scalar gravitational waves with present detectors [1]. With R. Apreda, M. Maggiore and A. Riotto he studied the gravitational wave background coming from true vacuum bubble collisions at the electroweak transition in supersymmetric models [2,3]. With P. Creminelli and R. Rattazzi he dealt with the cosmological viability of the Randall-Sundrum scenario [4]. Finally, with A. Dolgov and D. Grasso he studied the production of gravitational waves by cosmic turbulence [5]. In February 2003 he joined the IEM/CSIC Madrid Group as a network postdoc, where in collaboration with J. Garcia-Bellido he is presently analyzing the cosmological signatures of models of hybrid inflation. In April 2003 he attended the "Spring School on Superstring Theory and Related Topics" at ICTP, Trieste.

Five key publications:

[1] M. Maggiore and **A. Nicolis**, Phys. Rev. D **62** (2000) 024004 [arXiv:gr-qc/9907055].

[2] R. Apreda, M. Maggiore, **A. Nicolis** and A. Riotto, Class. Quant. Grav. **18** (2001) L155 [arXiv:hep-ph/0102140].

[3] R. Apreda, M. Maggiore, **A. Nicolis** and A. Riotto, Nucl. Phys. B **631** (2002) 342 [arXiv:gr-qc/0107033].

[4] A. D. Dolgov, D. Grasso and **A. Nicolis**, Phys. Rev. D **66** (2002) 103505 [arXiv:astro-ph/0206461].

[5] **A. Nicolis** (Madrid), arXiv:gr-qc/0303084.

Marieke Postma received her Ph.D. from the University of California, Los Angeles (UCLA) in 2002. Her Ph. D. research, under A. Kusenko, concerned several topics within astroparticle physics [1,2], as neatly summarized by the title of her thesis: *"High-energy physics from 10 billions years' worth of data: learning new physics from the big bang, stars and cosmic rays"*. After becoming a network fellow at ICTP, Trieste, she mainly worked on density perturbations in the curvaton and related scenarios [3,4,5].

Five key publications:

[1] **M. Postma**, "Solitosynthesis of Q-balls," Phys. Rev. D **65** (2002) 085035 [arXiv:hep-ph/0110199].

[2] A. Kusenko and **M. Postma**, "Neutrino production in matter with variable density, and a limit on the rotation speed of a neutron star," Phys. Lett. B **545** (2002) 238 [arXiv:hep-ph/0107253].

[3] **M. Postma** 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.

[4] K. Enqvist, A. Mazumdar and **M. Postma**, "Challenges in generating density perturbations from a fluctuating inflaton coupling," arXiv:astro-ph/0304187.

[5] **M. Postma**, "The curvaton scenario in supersymmetric theories," Phys. Rev. D **67** (2003) 063518 [arXiv:hep-ph/0212005].

Werner Rodejohann Born, 9/12/1972 in Erwitte, Germany
Matriculation 1992
Diploma in Physics at Dortmund University 1998
Ph. D. in Physics at Dortmund University 2001

Five key publications:

[1] **W. Rodejohann**, "Neutrino oscillation experiments and limits on lepton number and lepton flavor violating processes," Phys. Rev. D **62**, 013011 (2000) [arXiv:hep-ph/0003149].

[2] **W. Rodejohann** and K. Zuber, "Signatures of heavy Majorana neutrinos and HERA's isolated lepton events," Phys. Rev. D **62**, 094017 (2000) [arXiv:hep-ph/0005270].

[3] **W. Rodejohann**, "Cancellations in neutrinoless double beta decay and the neutrino mass matrix," Nucl. Phys. B **597**, 110 (2001) [arXiv:hep-ph/0008044].

[4] A. S. Joshipura, E. A. Paschos and **W. Rodejohann**, "A simple connection between neutrino oscillation and leptogenesis," JHEP **0108**, 029 (2001) [arXiv:hep-ph/0105175].

[5] S. Pascoli, S. T. Petcov and **W. Rodejohann**, "On the CP violation associated with Majorana neutrinos and neutrinoless double-beta decay," Phys. Lett. B **549**, 177 (2002) [arXiv:hep-ph/0209059].

Outreach activities

Talks to general audiences:

S. Sarkar (Oxford) gave several talks to schools.

Publications in the popular scientific press:

J. Ellis (Geneva) wrote a 'News and Views' article for Nature (Aug 2003) on *"Antimatter matters"* for Nature. N. Mavromatos (London) wrote on *"Bringing the heavens down to Earth"* for CERN Courier (Mar 2004).