STARTPAGE

HUMAN RESOURCES AND MOBILITY (HRM)
ACTIVITY

MARIE CURIE ACTIONS
Research Training Networks (RTNs)

PART B

"ForcesUniverse"

B1 SCIENTIFIC QUALITY OF THE PROJECT

B1.1. Research Topic

The proposed network entitled *Constituents, Fundamental Forces and Symmetries of the Universe* aims to gain further insights into the fundamental structure of the universe, namely its basic constituents, the forces mutually acting among them and the symmetries which underlie its theoretical description. With the advent of supergravity theories, superstring theory and M-theory it seems that the structure of matter and the structure of the universe are for the first time about to be expressed in a common language and, possibly, in the framework of a single unified theory. Over many years, this is a subject of enormous conceptual interest in theoretical particle physics, cosmology and also mathematics. The new theoretical ideas about space, matter and symmetries provide a fruitful stimulus to discuss processes beyond the Standard Model of particle physics which could be tested in future accelerator experiments like the Large Hadron Collider at CERN.

This network brings together a large number of European groups which work on the forefront of developing a unified description of all matter and interactions. It includes scientists who created some of the basic concepts within the field such as supergravity theories and many key aspects of superstring theories, and also many scientists who made some of the most important recent contributions. On the one hand, the network is composed of European groups that play an active role in the numerous collaborations of the previous network *The quantum structure of spacetime and the geometrical nature of fundamental interactions*, which will end in September 2004. Moreover several new members and groups will participate, opening up the research profile of the network in several new research directions. All members including the new ones have proved their ability in setting up inter-group research collaborations in many instances, and all groups show a high level of expertise in the training of young researchers and postdocs.

This network is directed towards deepening and further extending our knowledge of the three key ingredients that govern the structure of the observed universe: the basic constituents, known as matter or elementary particles, the forces among them and the symmetries which organize the theoretical description of constituents and forces. In string theory and M-theory, the known pointlike elementary particles are replaced by one-dimensional strings and higher-dimensional branes; the observed forces arise as effective interactions due to the exchange of strings; and finally the finite-dimensional symmetry groups of the Standard Model are extended in terms of supersymmetries and eventually in terms of infinite-dimensional algebras, whose full structure is still largely unknown in string or M-theory. It is remarkable that string theory provides in this way a fully quantized version of Einstein gravity without any disastrous divergences. Moreover there are intriguing relations among different forces in nature and also different formulations of string theory, commonly known as duality symmetries. During the last several years, some very important new theoretical observations and applications accompanied the development of (supersymmetric) quantum field theories, string and M-theory. These will also be subject of intensive research and training in the proposed network. First, it will be one of our prime goals to further explore the relation between supergravity and gauge forces, which is a manifestation of a subtle duality between open and closed strings due to the existence of D-branes. Another important aspect will be to close the gap between the Standard Model and string or M-theory by studying brane-world and flux compactifications from 10 or 11 dimensions. Finally the early history of our universe, i.e. the study of cosmology in string/M-theory, and the quantum structure of black holes will be one of our main research objectives. The proposed network will gather many of the leading scientists in each of these fields.

B1.2. Project objectives

Although the Standard Model of particle physics as a quantum field theory and also perturbative string theory at the first quantized level are very well understood, our understanding of M-theory, brane dynamics, non-perturbative duality symmetries and the infinite-dimensional symmetry that underlies string and M-theory, is still very incomplete, despite all the progress made during recent years. In this network, we are planning to attack some of the main unsolved issues in supergravity theory, string theory and M-theory, where we hope to make substantial progress by combining and focusing the various expertises and research interests that are present in all participating teams.

The research objectives will span the following range of topics which can be sorted as follows: investigation of the basic constituents of string and M-theory, in particular the dynamics and stability problems of membranes and D-branes; the fundamental symmetries of M-theory and string theory, in particular duality symmetries, the symmetries of actions with higher spin fields, non-commutative geometry and infinite-dimensional algebras; supergravity and gauge interactions, and in particular the correspondence between gravitational backgrounds in string theory and dual quantum field theories; the derivation of the Standard Model from string and M-theory compactifications, in particular from brane world models, flux compactifications and manifolds of exceptional holonomy; finally the relation between strings, branes, cosmology and black holes. All these topics are intertwined in a very non-trivial way, such that scientists working on one specific theme will also need also the knowledge and the input from the other fields. This will lead to a very positive and dynamic exchange of ideas. In order to coordinate the research efforts, we will nominate for each of the five fields one responsible senior scientist from our network (see also section B2.1).

More specifically, the five main research topics can be characterized as follows:

(i) Basic constituents: Strings & Branes

In string and M-theory, strings and branes are supposed to form the basic constituents of matter in the universe. Very importantly, the nature of these branes is two-fold; in supergravity field theories they appear as solitonic and finite energy solutions of the supersymmetric field equations, which describe non-trivial gravitational background spaces. In perturbative string theory, branes are the endpoints of open string excitations, which is the reason why they are also called Dirichlet branes or, in short, D-branes. In low-energy effective field theory the dynamics of D-branes can be described by an effective Yang-Mills theory with higher-derivative interactions which, for the Abelian case, is the well-known Dirac-Born-Infeld action. However, in the non-Abelian case the effective action is only known up to fourth order in the string slope parameter α'. It will be our goal to extend this analysis to higher orders, or to get a complete closed expression for the non-Abelian Born-Infeld action, which is also relevant to extra dimensional scenarios and brane world models as well. The boundary-state formalism is very useful to describe the dynamics of various D-brane configurations. We are planning to apply the boundary-state approach to D-brane configurations not yet considered in this context, such as intersecting branes in type I strings, with and without supersymmetry, wrapped branes, rigid branes at orbifold singularities etc.

A D-brane is unstable if the open string that describes the excitations of the brane contains tachyonic modes. The process by which the D-brane decays can then be understood in terms of tachyon condensation. During the process of tachyon condensation an infinite number of string excitations are involved. Therefore the infinite dimensional string symmetries should play an important role in the description of tachyon condensation. To study this relation between string symmetries and tachyon condensation is one of our scientific goals. In addition, while the end-result of this process is well understood for simple brane/anti-brane configurations, it has not been much discussed for general configurations like intersecting D-branes. Moreover it would be interesting to understand time-dependent decay processes in detail, where the tachyon plays the role of time. This subject relates very nicely to space-like brane configurations, to subcritical Liouville string theory with open strings and also to matrix models. Finally, the tachyon condensation process will also be very interesting for several phenomenological considerations, such as the Higgs effect in intersecting brane-world models or in the context of supersymmetry breaking.

(ii) Symmetries: supersymmetry, duality symmetry & infinite dimensional algebras

In general, our understanding of the basic string symmetries still needs a lot of further improvement. As has been known for some time, supersymmetry plays a key ingredient in all formulations of string and M-theory. It follows that the low-energy action is given in terms of supergravity field theories. Still many aspects of supergravity theories need a better and deeper understanding, such as the emergence of gauged supergravity theories with non-trivial scalar potential after string compactification with fluxes. Moreover, already at the supergravity level, intriguing new symmetries of the theory are becoming manifest, in particular the infinite dimensional symmetries which organize the spectrum and the interactions in a very non-trivial way. The supergravity symmetries also contain the so-called discrete duality symmetries, whose discovery was of utmost importance for the better understanding of non-perturbative physics in string and also in quantum field theory. The AdS/CFT correspondence is a beautiful manifestation of duality symmetry (see next paragraph). D-branes played a key role in establishing strong-weak coupling duality symmetries among seemingly different string theories, e.g. the heterotic/type II duality. It is believed that these non-perturbative duality symmetries are just the tip of a huge iceberg, which constitutes the infinite-dimensional symmetry algebra of M-theory. A possible way to get a handle on the high energy stringy symmetry group is to consider the plethora of higher-spin fields present in string theory, and which become massless in the limit of slope parameter $\alpha' \to \infty$. To construct an effective action for the higher spin field is a very important and difficult problem which some teams of our network plan to attack. Infinite dimensional string symmetries also play an important role in the tachyon condensation process which involves an infinite number of string states. This is also very interesting in the context of closed string tachyon condensation, which induces a 'decay' of the space-time geometry itself. Furthermore we want to extend the discussion about non-commutative space time geometry, which is a symmetry typically occurring in string theory with B-field background fields.

(iii) Gauge theories and (super)gravity: several correspondences

The AdS/CFT correspondence between gravitational and gauge forces in general states that a bulk supergravity theory resp. closed string theory is equivalent to a Yang-Mills resp. open string theory on the boundary of space-time (holography). This correspondence is best understood for 4-dim. $\mathcal{N} = 4$ supersymmetric Yang-Mills, which is dual to supergravity on AdS_5, and which can be explained by D3-branes in type IIB superstring theory. However much work remains to be done in order to establish an analogous correspondence for non-conformal and/or non-supersymmetric gauge theories, which should correspond to various deformations of the original anti-de Sitter backgrounds. One current problem is, for example, how to include matter fields into the AdS/CFT correspondence by considering wrapped or intersecting brane configurations.

In this way, one expects to obtain non-perturbative results on chiral symmetry breaking in a QCD-like theory from the dual gravitational theory. In a slightly different direction, it was recently shown that in the Penrose limit of the gravitational background corresponding to a pp-wave metric, the excitations of the background are in one-to-one correspondence with the so-called BMN operators of the dual gauge theory. We now plane to extend the quantum mechanical description of BMN gauge theory to further classes of operators, such as operators containing fermions, field strengths or covariant derivatives. Furthermore, theories with reduced supersymmetry and without conformal invariance should be analyzed.

Another manifestation of the open/closed string correspondence which we are to explore, is given by the topological large N transition in type II strings on (non-compact) Calabi-Yau spaces. It actually means that confinement in large N supersymmetric gauge theories can be described by a geometric transition on a Calabi-Yau space, where wrapped D-branes are replaced by fluxes through certain cycles of the Calabi-Yau manifold. This picture has recently led to the fascinating observation that the superpotential of certain $\mathcal{N} = 1$ supersymmetric gauge theories can be computed from a particular large N-matrix model. A quite parallel story has been found for N=2 susy gauge theories, where the prepotential is given by the discrete version of the large N matrix model. We hope to establish the direct link between these two statements, as well as their dual closed string explanation.

Finally, we also want to push forward the idea that holography might also be valid for de Sitter spaces, a question which is also important for string cosmology.

(iv) Compactifications: brane world models and connection to the standard model

One of the ultimate goals of string theory is to derive the Standard Model from string compactifications. This will eventually confront the new theories with future experiments (LHC, TESLA, Tevatron), where the search for supersymmetric particles, rare decays, flavor changing neutral currents, the search for extra dimensions and gauge coupling unifications will be central topics. Brane-world models with D-branes wrapped on Calabi-Yau homology cycles have turned out to have very attractive phenomenological features, since chiral fermions are located at the brane intersections. There are still many interesting problems in this class of string vacua that we are planning to investigate, such as the derivation of the effective action of the massless modes, the derivation of the MSSM, the issue of supersymmetry breaking, mass generation, the possibility of large extra dimensions etc.

Another class of string vacua intensively discussed recently are (warped) compactifications with background fluxes through Calabi-Yau cycles. These have the advantage that many moduli can by fixed by the background fluxes and supersymmetry can be partially broken. In field theory language they naturally lead to gauged supergravity theories. We are planning to systematically explore compactifications with background fluxes also in the presence of additional D-branes, their relation to non Calabi-Yau backgrounds, and their M-theory embedding via manifolds with G_2 structure.

(v) The early universe: supergravity, string and brane cosmology

Recent astrophysical observations on the cosmological microwave background and on supernovae explosions gave important information on the matter distribution and density fluctuations in the early universe. In particular the new experiments gave a lot of support for the hypothesis of an inflationary universe at very early times and also for a non-zero cosmological constants, which accelerates the present-day expansion of the universe. Moreover, many observations in astronomy give a lot of evidence for the existence of black holes in the center of galaxies, including our own galactic system. String theory, as a theory of quantum gravity, should give a satisfactory description of the quantum mechanical nature of black holes, the quantum physics at the very early times in the big bang, the physical nature of space-time singularities and in general the microscopic structure of space and time. At the very least, inflation or other scenarios, which predict the observed data, and the present value of the cosmological constant should find a reasonable explanation in string theory. Therefore it will be one of our important goals to study time-dependent backgrounds in string theory, cosmological (inflationary) backgrounds and de Sitter vacua with cosmological constant. We also like to confront our theoretical investigations with the new astrophysical experiments (such as Virgo or the ESA mission Planck) that are expected to soon produce refined, very interesting results on the history of the early universe.

B1.3. Scientific originality of the project

The Research Training Network we are proposing is scientifically very original since it combines the complementary expertises of several leading research groups in theoretical and mathematical particle physics in Europe in a very unique way. In particular we have combined teams who are worldwide leading experts in the fields of supersymmetric field theories, supergravity, superstrings, cosmology and also of mathematical physics. The team composition is such that input from mathematical physics can be used to make contact with future experiments, say at accelerators like LHC or with future astrophysical measurements. Therefore we regard ourselves not only as a network in one particular field, e.g. such as superstring theory, but our network shows a very high degree of multidisciplinarity, especially as regards the very close relation between modern mathematics and theoretical particle physics.

The quest for a unification of all matter and all forces is in our opinion an important scientific enterprise with many very original scientific concepts, ideas and developments. The Standard Model of elementary particle physics together with Einstein's theory of General Relativity are each in very good agreement with all known experimental phenomena at particle accelerators and in cosmology. Nevertheless the large number of undetermined parameters and the unexplained patterns of particles and forces in the Standard Model call for a unified description which also should include a quantum version of General Relativity. Supergravity theories and their quantum realization in superstring theory are the most promising candidates for this extension of the Standard Model. In particular, they have given birth to many new ideas and concepts for unification, and have proved themselves over many years as abundant sources for very original new developments in theoretical particle physics. On the one hand string theory has triggered an enormous exchange of ideas with modern mathematics in the fields of differential geometry, algebraic geometry and topology; this exchange has even introduced new areas of research in mathematics, perhaps most notably the idea of mirror symmetry. Also the relation between infinite dimensional symmetries in string theory and the work by Richard Borchers on infinite algebras is another good example of the interplay between physics and mathematics in our field. On the other hand, supersymmetric field theories, superstring theory, D-branes and M-theory were also of very high scientific value for new developments in particle physics phenomenology. The possible existence of large extra dimensions, which could be observed at new particle colliders, the investigation of orbifold field theories in higher dimensions (deconstructing gauge theories) and the role of anomalies on branes are excellent examples of the fruitful interplay between string theory and particle physics beyond the Standard Model. Finally, many new developments in quantum field theory were inspired by string theory, for example non-perturbative duality in supersymmetric field theories, non-commutative gauge theories, topological field theories and, last but not least, non-perturbative considerations in gauge theories via dual gravitational models, where several results can already be cross checked with Monte Carlo simulations in lattice gauge theories.

Several members of the proposed network have made very important and substantial contributions to the development of supersymmetric field theories, supergravity, superstrings and M-theory. Let us give some key examples of achievements were members of the network played a leading role. First, supergravity was founded by members of the proposed network, and major parts of the developments in supergravity were performed in Europe under the guidance of members of the network. This includes the formulation of the supergravity action and the formulation of 11-dimensional supergravity, which is one of the known cornerstones of M-theory. Also the discovery of infinite dimensional symmetry algebras in 11-dimensional supergravity, reduced down to low dimensions, is due to scientists of our group. Next, members of the network were the first to introduce the concept of the strong-weak coupling S-duality into string theory. In addition, important contributions in string phenomenology, such as supersymmetry breaking or more recently the formulation of the intersecting brane world models are due to members of the network. Also entropy calculations of $\mathcal{N} = 2$ supersymmetric black holes were mainly done by members of the network. Finally, during the recent years many important results in the field of the gauge theory versus gravity correspondence were obtained by scientists of the network, such as several verifications of the AdS/CFT correspondence for many cases, the discovery of a new perturbation series in the BMN limit of gauge theories and a perturbative proof of the matrix model conjecture of the $\mathcal{N} = 1$ superpotential. All this and many more results make clear that the teams of the network are able to perform very original and important scientific work with a lot of impact on future developments. Much of this was developed during the recent years in common collaborations among various participating teams of the existing RTN network or of the former EC networks. Therefore we are confident that the proposed network possesses a very high level of expertise in the areas of proposed research, for we have demonstrated that many of the main directions in theoretical high energy physics were originated and developed in part by members of our network.

Although we have gained a lot of new scientific insights into quantum field theory, superstrings and M-theory over recent years, and have broadened our knowledge of the possible basic structure of our universe, the entire subject is by far not completed: it will continue to be a very active and vital area of research for some time to come. Specifically, not only further exploration of already understood concepts will be necessary in the future, but also the recent appearance of new directions and the persistence of fundamental open problems predict that many years of original and sound scientific development in theoretical and mathematical high energy physics still lie in front of us. The development of new concepts and the invention of new ideas will be necessary in order to make further real progress in the field. Most importantly, a fundamental formulation of M-theory is still lacking: we do not precisely know the elementary degrees of freedom and the huge symmetry group of M-theory – the key to that problem could be a deeper understanding of supermembranes and of infinite dimensional symmetry algebras, which are related to higher spin fields in field theory language. Another very deep and basic problem is the question of vacuum stability and the problem of the apparently huge vacuum degeneracy in superstring theory. Precise predictions, which can really be confronted with experiments, can only be made after we have understood what the ground-state in string theory looks like, by what dynamical mechanism it is selected and what its stability properties are. The construction of brane models and flux compactifications on spaces with very few moduli (i.e. rigid spaces) are likely to open up new solutions in that direction. Concerning the stability of string vacua, we also have to know how string backgrounds develop in time, in particular shortly after the big bang. Ultimately we would like to understand why we so far observe only three macroscopic, large space dimensions in cosmology of accelerator experiments, we wish to know whether future colliders have the chance to discover new extra dimensions. The explanation of the apparently non-zero cosmological constant is a real challenge in string theory or supergravity theories; moreover the question whether the holographic principle extends also to de Sitter like space-times is very interesting from the point of view of counting degrees of freedom of the entire universe. We would also like to extend the investigation of the quantum properties of black holes to more realistic non-BPS black hole solutions, such as those astronomers observe in the centers of galaxies. Finally the interplay between geometry and the investigation of gauge theories via string theory must be pushed forward so that we learn more about non-perturbative physics in realistic gauge theories.

We are very confident that the proposed network, due to its past records, its present know-how and its human potential will substantially contribute to this ambitious and original scientific project. As the expertise is nicely distributed over the various teams in a complementary way, a lot of interdisciplinary interaction will take place, in particular between members who study the basic dynamical issues of strings and branes, and other members who have in mind cosmological and particle physics questions and applications. Thus a broad transfer of knowledge within this active area of research is foreseen. Motivating and training young researchers in this exciting field of science will hopefully have a very positive impact on theoretical and mathematical physics in Europe and world-wide.

B1.4. Research method

The research methods employed by the members of our network span a wide range of techniques and expertise which start with topics in modern mathematics like algebraic geometry, differential geometry on new manifolds with exceptional holonomy or non-commutative geometry, and range on to phenomenological investigations of the Standard Model. Moreover different branches of theoretical physics also intersect in our network. To successfully attack the problems outlined above, techniques of General Relativity and supergravity have to merge together with the methods of superconformal field theories and quantum field theory. Mathematical string theorists who work on D-brane categories and K-theory will have to work together with string model builders, who study the problem of supersymmetry breaking and derive the Standard Model from D-branes and strings. One of the new developments in string theory is certainly what one may call the "geometrization of matter", i.e. the geometrization of the internal structure of elementary particles. The process of developing quantum field theory and, in particular, this new geometric concept of matter has also brought about a new relationship between mathematics and physics. Certainly, the complexity of the notions involved and the subtlety of the methods required has forced physicists to seek an interchange with mathematicians more systematically than before, while striking new constructions, predictions, and problems arising in physics have attracted an ever growing number of mathematicians and have produced increasingly significant mathematical contributions. As particularly important examples for our project, we may mention: the discovery of mirror symmetry and M-theory, the study of Calabi-Yau spaces, Seiberg-Witten invariants, etc. The scientists united in this research proposal are fascinated by these perspectives and are strongly motivated by the large number of outstanding results which have recently been produced at the crossroads between theoretical particle physics and geometry, using methods and inspirations from various areas.

Of course, the specific choice of research topics depends to a large extent on individual skills and preferences. We trust that this intrinsic "gravitation" of our research enterprise will continue to inspire applicants and to attract gifted young scientists to do research in this fascinating area. Some of the necessary methodological tools to achieve the scientific goals of our network are the computation of string amplitudes in order to derive from higher derivative effective D-brane actions or the effective low-energy action of the Standard Model string excitations. Then we need to use the comparison of string amplitudes, e.g. those corresponding to Yukawa couplings at low energies, with topological quantities on Calabi-Yau manifolds. Turning on background fluxes, we will need mathematical methods for the investigation of manifolds with generalized spin connections with torsion. The study of the gauge/gravity correspondence will require the investigation of new space-time metrics and quantum field theory computations on the dual gauge theory side, where a matrix model description recently turned out to be a very important tool for deriving the superpotential of supersymmetric gauge theories. The study of solitons and space-like branes will be important for tachyon condensation and string cosmology. Finally the construction of an effective interaction for massless higher spin fields, possibly in anti-de Sitter space, will be crucial for the understanding of infinite dimensional string symmetries. In this context we will also have to get a better understanding of infinite dimensional (hyperbolic) algebras and their representations.

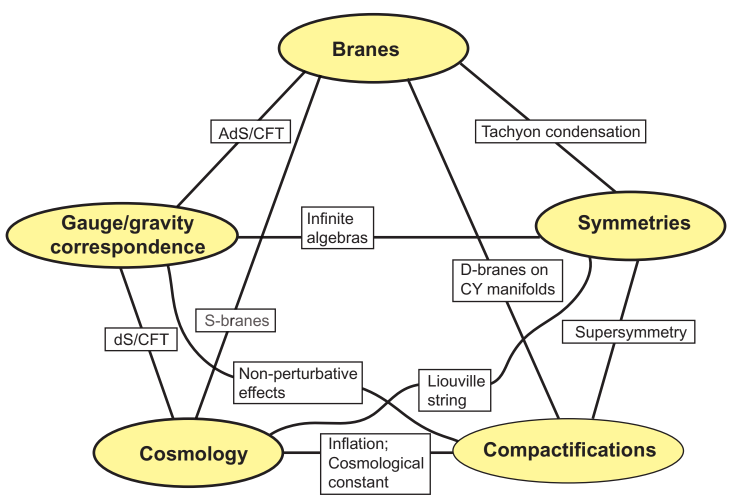
One very important component in the organization of scientific research in the participating teams will be the creation of working groups, devoted to the five topics described above. Each working group will be led by a senior scientist of our network. These coordinators will organize the working groups, which can meet for special events to train the young researchers; they will also set up lectures on recent developments in the field in our annual scientific meetings and training schools; and they will also stimulate the exchange of ideas with the other working groups in order to strengthen the overall unity and coherence of our network with respect to the research and training of young researchers. The nomination of these responsible scientists will be a new feature of the network activities as compared to the previous TMR and RTN network.

B1.5. Work plan

All five topics, introduced in section B1.2., are intertwined with each other. The goal of the network is to gain further insight into the basic, mathematical structures of strings and branes, of gauge theories and of the huge symmetries which underlie the unified description of matter and forces in nature. This knowledge will enter the formulation of compactification from higher dimensions, which will lead on to an effective description of string theories, D-branes theories and M-theory. The aim is to build realistic models, whose features can be tested in the next round of experiments. These tests could already become reality towards the end of the network in the year 2007 or 2008. Similarly, the new insights into strings and branes will have very interesting consequences for cosmology, which will again be confronted with new astrophysical experiments.

The persons in charge of the five research objectives will monitor progress in the different fields and will also, if necessary, update and adjust the initial milestones. During the network meetings we will discuss with the team representatives the specific tasks and will possibly ask for effort in new directions.

In order to make the flow between the different topics more transparent, we are showing the main common links in the following flow diagram:



In the following, we indicate the milestones for the five main research objectives as well as the tentative time schedule for when we expect to reach them:

1. **Strings and branes:**

   1a) *Non-Abelian D-brane action:* It will be important to know the higher derivative terms in the effective Non-Abelian gauge action on the world volume of a stack of N D-branes. The non-Abelian D-brane action will be important for the formulation of the effective action of realistic brane world models.

   1b) *String/string duality and string states:* The derivation of the non-Abelian D-brane action will also be relevant for checking the string/string duality symmetry between the type I string with open strings ending on D-branes, and the heterotic string with only closed strings. In addition, in order to check string/string duality symmetries, the study of the properties of higher string states is important also in view of possible large radius compactifications.

   1c) *Derivation of tachyon condensation for various D-brane configurations:* This is important for phenomenological problems like the Higgs effect as well as for time dependent, cosmological problems.

   1d) *D-branes in non-trivial backgrounds:* This is important for D-branes wrapped around cycles of internal spaces and D-branes in time dependent backgrounds.

2. **Gauge theory/gravity correspondences**

   2a) *Generalizing the AdS/CFT correspondence:* This will involve the extension of the AdS/CFT correspondence for general gauge groups as well as gauge groups with matter.

   2b) *The AdS/CFT correspondence in the plane wave limit:* This will involve the study of new large N limits in gauge theories, as well as an extension of the description of BMN operators.

   2c) *Geometric transitions, confinement and matrix models:* We will explore geometric transitions from branes to fluxes on Calabi-Yau space which are related to the confinement mechanism in the corresponding gauge theory. The corresponding matrix model picture needs further better understanding and verifications.

   2d) *Holography for de-Sitter spaces:* This is important for the understanding of the dS/CFT correspondence and also for cosmological solutions in string theory.

3. **Underlying symmetries**

   3a) *Derivation of higher spin actions and their symmetries:* This is crucial for the understanding of infinite dimensional symmetries in string and M-theory related to higher spin fields in the limit $\alpha' \to \infty$.

   3b) *Space-time symmetries and decay processes of space-time:* This is important to understand the role of space-time in string theory and will also play a role in string cosmology. In string theory the decay of space-time is related to the condensation of a closed string tachyon mode.

4. **Compactifications and the connection to the standard model**

   4a) *Derivation of the MSSM from brane worlds and flux compactifications:* It will be important to demonstrate that the minimal supersymmetric Standard Model, or mild extensions of it, can be derived from string theory via brane or flux compactifications.

   4b) *Derivation of the low-energy effective action from brane worlds and flux compactifications:* This will involve the computation of the effective superpotential, the gauge kinetic terms and the Kähler potential, which is important for the Yukawa couplings, gauge coupling unifications etc. The knowledge of the low-energy effective action will be the basis for comparing brane world models with the future experimental results.

   4c) *Supersymmetry breaking in brane world models and flux compactifications:* This will involve the study of various supersymmetry breaking mechanisms like by fluxes, gaugino condensation and the Scherk-Schwarz mechanism. The computation of the associated soft-SUSY breaking parameters will be also performed.

5. **String and Brane cosmology:**

   5a) *Obtaining inflation from string compactifications:* This involves the study of vacua where moduli are stabilized from induced potentials. A realistic setup which will produce naturally early time inflation (and/or late time acceleartion) will be studied.

   5b) *The study of time-dependent solutions in string/M- theory and the effective supergravity:* This is an important task that addresses more conceptual problems in comsology like the resolution of initial singularities and the nature of the correct formulation of the cosmological evolution problem.

   5c) *The study of (string) cosmology in the context of brane-worlds:* New cosmological processes as possible in this context as energy can be either on the brane, or in the bulk, always affecting the cosmological evolution. Moreover, the echange of energy between brane and bulk may provide strong constraints on model building as well as interesting new realisations of cosmological acceleration.

With present knowledge we expect to obtain results on these items in the following time schedule, although it is often difficult in basic research to make precise predictions on the time schedule.

First year	Mid-term	Third year	Final
1a), 1d), 2a), 2b) 5a)	1c), 2c), 2d), 3a), 4a) 5b)	1c), 3b), 5b), 5c)	1b), 4b), 4c), 5c)

The distribution of the five scientific topics to the various teams can be structured as follows:

	Strings/branes	Gauge/gravity	Symmetries	Compactifications	Cosmology
Berlin		x		x	x
Potsdam			x	x	x
Barcelona	x		x		x
Madrid	x	x		x	
Bures-sur-Yvette		x		x	x
Paris ENS	x		x	x	x
Copenhagen	x	x	x		x
Dublin		x	x		
Frascati	x	x		x	
Torino	x	x		x	x
Leuven	x	x	x		x
London	x	x	x		x
Neuchatel	x	x	x		
Patras		x	x	x	x
Sofia	x	x	x		
Utrecht	x	x			x

B2 TRAINING AND/OR TRANSFER OF KNOWLEDGE ACTIVITIES

B2.1. Content and quality of the training and transfer of knowledge programme

Quantum field theories, supergravity theories and superstring theory are subjects which has gone through various developments during recent years. It is the aim of our network to provide to our young researchers with a stimulating and active research and training environment. There are several aspects of the present proposal which are particularly tailored to achieve this. As explained under B2.3, the very application and selection procedure for the young researchers is already a concerted effort. Furthermore, the organization of schools and workshops specially adapted to young researchers and, as emphasized above, the creation of the five working groups, coordinated by five senior scientists, will additionally ensure that the five general topics will be brought together such that a coherent training program is offered to all young researchers.

The network will appoint post-doctoral researchers (experienced researchers) as well as PhD positions (early stage researchers). More concretely, every node will have at least a two year postdoc position, while two larger nodes will have 36 person-months for postdocs. This will ensure that every node will contribute to the common research objectives in a substantial way. In addition every node will have 24 person-months for early stage researchers. In total we are applying for 408 person-months for experienced researchers and for 384 for early-stage researchers. As it is clear from the list of key scientific staff (see section B3.1.) every node has sufficient capacity and expertise to host the young researchers and to contribute to the training program in a viable way. In fact, all teams have a high international reputation and have proven their ability to carry out fundamental research and to train young researchers in numerous instances in the past.

The training program addresses both post- and pre-doctoral researchers, and senior researchers will benefit from the program as well. There will be both individual and common components in our training program. We expect that the individual training and common program will be equally important for the scientific education of our young researchers. Specifically, the training program will consist of the following building blocks:

(i) Individual training within the research groups

As it is clear, a lot of training of the young researchers will be offered by the individual supervision, seminars, lectures, courses, discussions and collaborations with each of the participating teams. This will of course influence the daily scientific life of the young researchers to a great extent. The style of this individual training may vary from group to group, but it will follow the general scientific standards of our field, which are guaranteed by the excellent scientific level of all the groups selected for the network. For the early-stage researchers (PhD-students) the individual training will be of particular importance, as many of them will be at the very beginning of their scientific careers. Therefore all PhD-students of the network will be closely integrated into the existing PhD-programs and PhD-schools of the participating teams.

(ii) Individual visits

The second component of the individual training consists of frequent visits of both young as well as senior researchers to various nodes. These visits will complement the individual research expertises and skills of the teams. The visits of the senior scientists will usually involve a series of lectures or seminars on their own research such that the inviting node will benefit from it. Visits of young researchers will give them the opportunity to work in different research environments and groups, and in particular have the purpose of stimulating or continuing collaborations within the network. Also for the early-stage researchers the individual visits will be of very high value, since they will learn about different research environments and different points of view on scientific problems possibly for the first time in their scientific careers.

(iii) The annual network conference

The annual network conference is one of the main research and training events of our network, where most of the young researchers, as well as most of the senior scientists, come together for one week. This workshop will usually be hosted by one of the network nodes and normally takes place during the autumn, although this is not necessarily required. The midterm meeting will be combined with one of the network conferences. The conference program is planned to contain several, typically five or six, lectures by senior scientists on research topics which are of general interest and reflect the current status of the field. The lectures will always be complemented by discussion sessions where the young researchers are encouraged to ask also basic questions concerning the lectures. The coordinators of the working groups should influence the selection of the topics and the speakers of these general conference lectures. In addition the workshop will also consist of a number of seminars where mostly young researchers have the occasion to present their own scientific results. Finally, the main administrative meeting of the contact persons of all teams will be held during the network conferences.

(iv) The annual network school

The school is mainly intended for all young pre- and post-doctoral researchers of the network and focuses on topics that are at the moment particularly important to the aims of the network. Its purpose is to quickly bring the young researchers up to a level where they can actively contribute to the research program of the network. The school should provide a close contact between the lecturers and the students, leaving also a lot of time for discussions, both on an individual level and also in special discussion sessions. Again, it will be one of the duties of the working group coordinators to contribute to the organization of the network schools.

(v) Working groups and mini workshops

The creation of five working groups is a new element in the training program compared to previous networks. The coordinators of the working groups will organize smaller meetings and lecture series in one of the nodes during the year. All researchers of the network are of course invited and are welcome to join these special training events, but as these mini workshops and schools will concentrate on some specific topics, the participation will be restricted. In this way the working groups provide a link between the individual and the common training program. They will stimulate the exchange of ideas and collaborations among the young researchers in order to strengthen the overall unity and coherence of our network with respect to research and training.

As demonstrated in section B6.3, we will also take very seriously gender issues in our network. First, we will ensure in the selection committee that there is the best possible balance in the appointment of network researchers. We have several outstanding senior female scientists as key scientific staff in our network, and as such female researchers will be substantially represented in all decision-making. This will of course also have a positive impact on the selection of the speakers in the network schools and conferences.

In the following we outline the training program in all of the participating teams:

The Berlin node will train two early stage researchers for 12 months each or one early stage researcher for 24 months and provide 24 months of training for experienced researchers paid by the network. The latter months can be extended by grants of the German research foundation (DFG) within the priority program in string theory or other funds to a postdoc position of 36 months. The training for the young researchers will also benefit from the DFG supported graduate school (Graduiertenkolleg) at the Humboldt-University in Berlin. Moreover the researchers will enjoy the two weekly common seminars on quantum field theories, superstring theories and mathematical physics, where one seminar is usually hold by external invited speakers and the second is an internal journal club seminar on recent interesting developments. In addition in Berlin there are about twice a year *Andrejewski lectures series* on mathematical physics by well-known senior scientists, which complement the training program in a nice way. The node provides annually about 3-4 completed Ph.D. degrees.

The Potsdam node will train two early stage researchers for 12 months each or one early stage researcher for 24 months and provide 24 months of training for experienced researchers paid by the network. Both, the early stage and the experienced researchers will be part of larger programs which receive local funding and which are augmented by external grants, e.g. from the German Research Foundation (DFG), the German-Israeli-Foundation and the Humboldt Foundation. In Potsdam the young researchers will be integrated into the Max-Planck-International Research School which provides graduate level lecture courses, weekly seminars and a journal club, in addition to the usual institute seminars. At the University of Bonn the early researchers will be incorporated in BIGS (Bonn International Graduate School of Mathematics, Physics and Astronomy) with an extended program of advanced seminars and lecture courses. The young researchers will thus be embedded in an already existing active research and training program where they will meet and collaborate with Ph.D. students and postdocs from all over Europe and the rest of the world. The Potsdam node awards about 4 Ph.D. degrees annually in the area covered by the network.

The Barcelona node will train four early stage researchers for 6 months or two early stage researches for 12 months and provide 24 months of training for experienced postdoctoral researchers paid by the network. Additionally, local sources like the Spanish Ministries of Education and Research and the International Graduate School of Catalonia could provide additional financial for pre and postdoctoral members of the node both in Barcelona and Valencia. The quality of training of the young researches will be very high because both the Ph.D. (postgraduate) teaching programs in Theoretical Physics at Barcelona and Valencia have been recognized as being ‘of excellence’ by the Spanish Ministry of Education and the Generalitat de Catalunya. The researchers will be able to attend weekly seminars on quantum field theories and supertring/M theory, the workshop organized by the Benasque Center of Physics, etc. The node produces annually about 3 completed Ph.D degrees.

The Madrid node will train four early stage researchers for 6 months or two early stage researchers for 12 month each and provide 24 month of training for experienced researchers paid by network. The later months can be extended by grants of the Spanish ministry of education and the Spanish ministry of science to two full postdocs positions of 24 months, in Madrid and/or Santiago and Oviedo. The researchers will enjoy the common seminars and education programs at the Instituto de Fisica Teorica in Madrid. Especially they can become familiar with techniques of conformal field theory, quantum field theory, string phenomenology, supergravity, supersymmetric field theory. The node provides annually about three completed PhD degrees.

The Bures node will have 24 months of early stage researchers and 24 months of experienced researchers each. The PhD students at IHES will be affiliated with Ecole Normale or Ecole Polytechnique, where they could get the PhD degree. The young researchers will participate in several weekly seminars: string theory seminar at Ecole Polytechnique, theoretical physics seminar at IHES, all-Paris string theory seminar, currently held at Institut Henri Poincare in Paris (http://danae.lpthe.jussieu.fr/string/) . They will also benefit from the theoretical physics seminars at University Paris-Sud (Orsay), CEA (Saclay), or seminar on mathematical physics at IHES. The young researchers will benefit from the interactions with the working groups in the South Paris area, which should permit them to study the supersymmetric gauge theories, M-theory compactifications, string cosmology, bulk and boundary conformal field theories, as well as D-brane and orientifold techniques, derived categories, and supersymmetry breaking. The node provides annually about 3 completed PhD degrees (at Ecole Polytechnique).

The Paris node will train four early stage researchers for 6 months or two early stage researches for 12 months and provide 24 months of training for experienced researchers paid by the network. the latter months will be extended by grants of the " Centre National de la Recherche Scientifique" (CNRS) and the " Ministère délégué à la Recherche et aux Nouvelles Technologies". The training of the young researchers will benefit from the ENS graduate school (Ecole Doctorale 107). There are two common seminars per week in subjects related to the network and workshops organized by the members of the two groups of the Paris node. Furthermore the LPT-ENS is part of the Physics Department of the Ecole Normale Supérieure, which has a wide range of research and teaching activities. These include a weekly colloquium, advanced graduate courses and an annual Summer Institute. In the wide-Paris area there are several other institutions including the Institute Henri Poincaré, the LPTHE and LPNHE of the University of Paris VI, the University of Paris VII at Tolbiac, the College de France, the Institut d'Astrophysique de Paris (IAP), the Ecole Polytechnique and the Commissariat à l'Energie Atomique CEA at Saclay, offering seminars and lectures on mathematics, experimental particle physics, cosmology and other topics related to the actual proposal. The node provides annually about 3-4 completed Ph.D. degrees.

The Copenhagen node will train two early stage researchers for 12 months or one early stage researcher for 24 months and provide 24 months of training for experienced researchers paid by the network. The training of the young researchers will benefit from various local activities including a weekly study group on recent developments in string theory; two Nordic meetings every year where they will also be exposed to the most recent developments in string theory and where they will have the opportunity to present their own research in a 30 minute seminar; a weekly high energy seminar and a weekly interdisciplinary seminar in theoretical physics. The Copenhagen node is also a Marie Curie Training Site so the young researchers will be trained together with others coming from outside Denmark.

The Dublin node will train two early stage researchers for 12 months or one early stage researcher for 24 months and provide 24 months of training for experienced researchers paid by the network. Training of young researchers will benefit from strong existing graduate program at Trinity College in theoretical physics and mathematics (Department of Pure and Applied Mathematics), from two weekly seminars (one at Trinity College on Quantum Field Theory and another at Dublin Institute for Advanced Study), several workshops organized during the academic year in Dublin area (for example - Irish Quantum Field Theory workshop which exists for more than 10 years) and from Hamilton Mathematics Institute visitor program at Trinity. Researchers will also benefit from closed contacts with IHES in Bures where professor Shatashvili spends part of the time during academic year.

The Frascati node will train four early stage researchers for 6 months or two early stage researches for 12 months and will provide 36 months for experienced researchers paid by the network. It should be possible to extend the training periods for experienced researchers using grants of the italian Institute for nuclear research (INFN) or of research grants of the teams of the node for research in string theory. The young researchers will also profit from the PhD programs which are active in the node. Both them and the more experienced researcher will participate to the common seminars on String Theory which are given at least once a week and to the study group on recent interesting developments in the field. The node provides annually about 4 completed Ph.D. degrees in topics related to string theory.

The Torino node will train two early stage researchers for 12 months each and provide 36 months of training for experienced researchers paid by the network. It is foreseen that the latter months may be extended by further 12 months with grants coming from the Italian Ministry of Education (MIUR) in order to provide two full post-doc positions of 24 months, to be shared between the Universities of the Torino and Milano areas. These researchers will benefit from the expertise of a very articulate group capable of leading them into the heart of forefront research through basic techniques of supersymmetric quantum field theories, supergravity, superstrings and d-branes as well as mathematical tools of differential geometry and non-commutative spaces. Next to weekly seminars and journal clubs held locally, the young trainees will enjoy the networking possibilities within Italy that originate from the Italian excellence program in String Theory, which is coordinated by the Torino pole and connects all the major italian string groups with common workshops and research exchanges. The five Universities of the Torino node provide an annual average of 6-7 completed Ph. D. degrees in this field.

The Leuven node will train four early stage researchers for 6 months or two early stage researches for 12 months and provide 24 months of training for experienced researchers paid by the network. The latter months will be extended by grants of the Belgian Network of Excellence (IAP) (see under B4.3.) to full postdoc positions of 24 or 36 months in Leuven and the two Brussels universities. The researchers will enjoy the common seminar and education programs available in that context and especially get to know techniques of conformal tensor calculus, superalgebras, special geometries, constructions of brane actions, cohomology techniques in gauge theories, black hole and cosmology applications of string theory. The node provides annually about 4 completed Ph.D. degrees.

The London node will train two early stage researchers for 12 months or one early stage researcher for 24 months, and will provide 24 months of training for an experienced researcher under network support. In addition, the London group has an internationally recognized programme at MSc level that provides courses in a wide range of active research topics in theoretical physics. In addition, we have at a given time around 10 postdoctoral researchers supported by other granting organizations, which provides for a very lively local research culture. Our postdoctoral researchers have the opportunity to give short lecture courses in our MSc programme, and at the same time, we have three ongoing weekly seminar series, plus occasional longer short courses given by senior visiting scientists. We also participate actively in London-wide seminar programs, and have a range of research collaborations with other research groups in the London area. The Edinburgh subnode also has strong links with a wider research community, both in the Maths-Physics context within Edinburgh University and also links with the International Centre for Mathematical Sciences. The node overall produces annually about 4-5 completed

PhDs.

The Neuchatel node will train two early stage researchers for 12 months each and provide 24 months of training for experienced researchers paid by the network. These months will be supplemented by either university positions or by positions financed under grants obtained by the groups (Swiss National Science Foundation essentially), to offer longer term postdoctoral positions and to bring early stage researchers to the PhD level. These grants will also allow to develop collaborations between the two participating groups, organize common seminars and topical workshops. Early stage researchers will have access to the local postgraduate training programs and regular seminars, all researchers will have access to the advanced training program organized in common by swiss universities. The node will provide each year three completed PhD degrees.

The Patras node will train two early stage researchers for 12 months each or one early stage researcher for 24 months and provide 24 months of training for experienced researchers paid by the network. There are possibilities to extend the months of both early stage and experienced researchers to full positions of 36 months each by the grants "C. Caratheodory" provided by the programme for the advancement of basic research at the University of Patras. Moreover, the researchers will enjoy the regular weekly seminar on theoretical and mathematical physics and participate in the advanced schools and conferences, which are regularly organized in Greece with the participation of many well-known senior scientists and compliment the training programme. The node provides annually 1 (and it will soon be 2) completed PhD students.

The Sofia node can provide a 24-month training program for one early stage researcher (Ph.D. student) and can furthermore provide 24 months of training for one experienced researcher (Post-Doc) or, alternatively, 12 months training for two experienced researchers each. The trained researchers will be able to attend the two regular seminars organized by us on a weekly basis. The first one is a general seminar devoted to reports (sometimes, talks given by foreign visitors) on modern developments in quantum field theory (including string theory) and mathematics relevant to theoretical physics. The second seminar is a specialized one on Lie symmetries and applications in physics. Furthermore, members of the Sofia group are delivering on a regular basis various graduate lecture courses on advanced topics of theoretical physics such as conformal symmetries, quantum groups, etc. organized in collaboration with the Physics Department of Sofia University. In the last few years the Sofia node has provided 1 completed Ph.D. thesis annually. In the last few years, the Craiova subnode provided annually about 1 completed Ph.D. degree.

The Utrecht node will train early stage researchers for 24 months and provide 24 months of training for experienced researchers paid by the network. These training periods, covering at least 12 months each, can be extended by grants of the Dutch Research Foundation (FOM) or the participating universities, to a full postdoc position of 24 or 36 months. The training of the early stage researcher will take place within the context of the Dutch Research School of Theoretical Physics (DRSTP). Amongst other activities the DRSTP offers the early stage researchers a two-week training school (AIO-school) which annually takes place in the Netherlands. Both the early stage and the experience researcher will participate to the seminar programs in Utrecht and Groningen. The node provides annually about 4 completed Ph.D. degrees.

B2.2. Impact of the training and/or transfer of knowledge programme

In the following we like to describe three of the major goals of the network training programme:

Training of the young researchers for an academic career:

The described training provides the specific knowledge necessary in the field of theoretical particle physics, such as quantum field theory, string theory, cosmology, mathematical physics and their relations to phenomenology. In this way the planned training and the transfer of knowledge activities of the young researchers will definitely assist them in their future academic careers, as all network participants had already very positive experiences in this respect from previous networks. Indeed, most of our former network young researchers have found very good positions in various institutes worldwide.

Training of the young researchers for a non-academic career:

The training programme will also provide many skills which are important for non academic careers, since some of the early stage researchers may eventually decide to continue their career outside the specific field of theoretical physics. In this context, the training will provide skills in communication, presentation, analyzing problems from a broader perspective, i.e. problem solving techniques, modeling management, international experience, collaborations with different teams and different styles of work etc. In particular the interdisciplinarity of the network will help the researchers to realize common structures and connections between different fields of work. Among others it is especially this intellectual independence which is nowadays required for successful careers inside as well as outside academics.

The European aspect of the training programme:

It is of vital importance for basic science in Europe to offer the young researchers an excellent research and training environment. The proposed EU network will play a very important role in this respect. Having excellent EU networks of the type proposed in this project allows Europe to focus the resources in basic sciences, in this case in mathematically oriented physics, in a very effective way. To bundle forces and means is indeed very necessary, since on the one hand, funding of basic science is rather limited worldwide; but on the other hand theoretical particle physics beyond the Standard Model are a very active area, where a lot of competition between scientists and institutions takes place. So the proposed network will enable us to compete with the centers of excellence in the US and other countries, and hence will largely contribute to the visibility of European basic research all over the world. Therefore the funding of these kinds of networks is very important for the future of basic sciences in Europe.

The exchange of young researchers and the transfer of knowledge among widespread institutions in Europe with common research interests has already had a very important influence on the scientific development of the participating teams. In fact, the creation of the EU networks has triggered and stimulated European collaborations in a very profound and deep way. We are very confident that this will be continued by the proposed network. In addition, the training and the transfer of knowledge programme of the network will have an important impact also at national levels. In fact, it will help to close a gap in hiring postdocs, since many of the nodes support mainly PhD-students. Finally, at an international level, the opening of the network positions to applicants from outside EU will help to provide a transfer of knowledge in basic sciences from outside Europe into the EU and also vice-versa. As an effect of this internationalization, Europe will become even stronger in theoretical particle physics.

The participation of the Bulgarian team in Sofia, which is supported by scientists in Craiova (Romania), will be of large mutual and reciprocal benefit for all teams. First this node has several excellent scientist of very high international reputation, whose scientific interests fit nicely with the research objectives of the network. Second, there are already close ties of the Sofia node with researchers of our network, in particular in the Paris area. This will ensure a smooth scientific integration of this node into the network. It is clear that the Eastern European team will also profit very much from the common training programme, as the funds for high level scientific training are still very much restricted in this node. Therefore the network will make a substantial contribution towards the scientific integration of this Southern European region, which belongs to a candidate country for the EU, into Europe as a whole.

B2.3. Planned recruitment of early-stage and experienced researchers

During the four year contract period we are planning to appoint 408 person-months of experienced researchers and 384 of early stage researchers in our network. The training and education of these young researchers is one of the central tasks of our future network activity. As follows from these numbers, the main part of the financial contribution of the EU is foreseen for post-doc positions (about 51.5 % of the person-months). These experienced young researchers (post-docs) will be essential for achieving the scientific aims of our network, since many of the highly involved research objectives should be carried out by young researchers shortly after obtaining their doctoral degree. Of course the research work and the transfer of knowledge of the experienced young researchers will also benefit from the general training programme of the network. Past experience in previous networks taught us that there is indeed a very large number of highly qualified young postdocs who are eager to carry out research in European institutes. This will allow us to apply very high selection criteria, as typically for every free position there will be many excellent candidates. Therefore the relatively large number of requested postdoc positions is necessary in order to compensate for the lack of a sufficient number of post-doc positions funded by the participating institutes or by the national funding organizations. Estimating the budget, we have ensured that every team has at least one regular two year post-doc position (either paid by a regular contract or, if allowed by national rules, in some institutes by a stipend); each team can decide whether they would like to prolong a two year post-doc position to three years or longer by its own funds.

In addition, a substantial amount of the budget (about 48.5 % of the person-months) is devoted to early-stage researchers, in our field typically PhD-students. We are confident that these positions will be of very high value in order to bring young PhD-students to the forefront of basic research as early as possible during their scientific career. Of course the aspect of scientific training of early stage researchers will be extremely important for them to make fast scientific progress. The planned EU contract duration (if possible by a stipend) of the PhD-students will typically be for one or two years. Based on the 'normal' PhD time of about 3-4 years in our field, this will allow the PhD students to spend 24 months in the home institute during their graduate studies plus one or two years possibly in another institution. In addition also shorter 6 months stays for PhD-students will be possible in order to learn specific techniques in the host institutions. Of course the PhD-students can also perform their entire PhD work in the host country, in case the fellowship is supplemented by other national funds. All PhD students will be well integrated into the existing PhD schools and programs at their foreign host institutes, and the doctoral degree will be given according to the individual regulations of the supervising institutes (depending on the circumstances, the official supervisor could either be a foreign host institute or from the original home institution).

All open positions of the network will be announced and published on the home Web page of the network and also on the Web site of CORDIS. Furthermore, announcements will be sent to the main institutes in Europe and overseas and also to a list of senior people who will be invited to suggest highly qualified candidates. The announcements for positions, usually starting at the beginning of the academic year in the autumn, will appear during the autumn of the previous year; interested researchers should then apply online on the Web site of the network, ensuring that at least three recommendation letters from senior people are also sent directly to the network. The selection of the best qualified candidates will usually take place during January by a selection panel, which consists of the contact persons from all the participating teams. This early time schedule will ensure that despite international competition the very best candidates will have a chance to accept a position within our network. Of course, the selection committee will strongly encourage the exchange of talented young researchers among the participating nodes. In particular PhD students, who have just finished their doctoral degree, may have the opportunity to have their first postdoc in another node of the network. Furthermore, the exchange of early-stage researchers among the various nodes will be vastly boosted by the network. The presence of all participating teams will ensure that any difficulties that might occur in the recruitment of the young researchers will be effectively solved by re-balancing between nodes, i.e. should one node have temporary problems in filling its positions, then another node can hire in substitution.

Of course, the main selection criteria of the network researchers will be based on scientific qualifications. In addition, we will try as much as possible to address gender issues in our network, in order to correct the imbalance between men and women in the number of appointments. To implement equal opportunities for male and female researchers in the best possible way, the selection committee will strongly encourage the application of young female scientists.

The following table gives the planned recruitment for the network:

	Early-stage and experienced researchers to be financed by the contract			Other professional research effort on the network project	
Network Team	Early-stage researchers to be financed by the contract (person-months) (a)	Experienced researchers to be financed by the contract (person-months) (b)	Total (a+b) (c)	Researchers likely to contribute (number of individuals) (d)	Researchers likely to contribute (person-months) (e)
1. Berlin	24	24	48	15	360
2. Potsdam	24	24	48	12	300
3. Barcelona	24	24	48	14	252
4. Madrid	24	24	48	14	336
5. Bures	24	24	48	15	360
6. Paris	24	24	48	15	360
7. Copenhagen	24	24	48	14	300
8. Dublin	24	24	48	7	180
9. Frascati	24	36	60	20	480
10. Torino	24	36	60	22	600
11. Leuven	24	24	48	18	432
12. London	24	24	48	15	360
13. Neuchâtel	24	24	48	12	320
14. Patras	24	24	48	7	168
15. Sofia	24	24	48	14	173
16. Utrecht	24	24	48	30	720
Totals	384	408	**Overall Total** 792	244	5701

B3 QUALITY/CAPACITY OF THE NETWORK PARTNERSHIP

B3.1. Collective expertise of the network teams

B3.1.1 Node Berlin

The node consists of the research group at the Institute of Physics, Humboldt-University in Berlin.

Key scientific staff:
Dieter Lüst: Professor; **Coordinator**; compactifications, string and brane model building; 60%
Gottfried Curio: Assistant Professor; flux compactifications, M-theory; 50%
Harald Dorn: Associate professor; AdS/CFT, non-commutative geometry; 40%
Johanna Erdmenger: Research group leader; AdS/CFT; 60%
Gabriel Lopes Cardoso: Senior research fellow; compactifications, black holes; 60%
Stephan Stieberger: Senior research fellow; string effective actions, duality symmetries; 50%

In the past, members of this group have made some basic contributions to the discovery of string duality symmetries (together with members of the Madrid group), which were very important for the non-perturbative understanding of string theory, the construction of 4-dimensional string compactifications, the construction of intersecting brane world models, flux compactifications and the effective action of 4-dimensional strings. There are successful collaborations with the Bonn, Leuven, Torino and Utrecht groups. The specific **areas of current research** are

- String Intersecting brane world model building
- Flux compactifications
- Manifolds of exceptional holonomy
- AdS/CFT correspondence with defects
- Non Commutative Quantum Field Theory
- Geometrical engineering of supersymmetric gauge theories

The **future goals** include the understanding of phenomenologically realistic models in string theory, supersymmetry breaking, flux compactifications superpotentials and moduli stabilization, manifolds with exceptional holonomy, deconstruction of higher dimensional gauge and string theories and string cosmology.

Significant recent publications:

1. R. Blumenhagen, L. Görlich, B. Körs, D. Lüst, *Noncommutative compactifications of type I strings on tori with magnetic background flux*, JHEP **0010** (2000) 006, hep-th/0007024.
2. R. Blumenhagen, B. Körs, D. Lüst, T. Ott, *The standard model from intersecting brane world orbifolds,* Nucl. Phys. **B616** (2001) 3, hep-th/0107138

B3.1.2 Node Potsdam

The node consists of the research group of the Max-Planck-Institute of Gravitational Physics in Golm and will be supported by a group of the Institute of Physics at the University of Bonn.

Key scientific staff:

From the **Max-Planck-Institute in Golm:**
Stefan Theisen: Professor; **scientist in charge**; string dualities; string compactifications; AdS/CFT 50%
Gleb Arutyunov: research staff; AdS/CFT; integrable systems; 60%
Kasper Peeters: research staff; String loops, D-branes, M-theory; 60%
Jan Plefka: research staff; Matrix models, AdS/CFT, 60%

From the **University of Bonn:**
Hans Peter Nilles: Professor; string phenomenology; 50%
Rainald Flume: Professor; quantum field theories; 20%
Stefan Förste: Assistant Professor; string constructions; 60%

Members of the group in **Golm** obtained basic results in the formulation of the effective string action, Calabi-Yau compactifications and mirror symmetry and in the AdS/CFT correspondence. The **Bonn** group has made very important contributions to the formulation of supergravity theories, the construction of 4-dimensional string vacua, supersymmetry breaking in string compactifications, the phenomenology of string and M-theory as well as in cosmology.

There are successful collaborations with the Berlin, Madrid, Milan, Paris, Neuchâtel, Utrecht groups. The specific **areas of current research** are

- explicit string model constructions
- Susy breakdown in field and string theories
- branes and extra dimensions
- cosmological aspects of string theory
- AdS/CFT correspondence
- quantization of string theory in non-trivial backgrounds
- string theory and supersymmetric gauge theory
- matrix models

Our **future goals** include the construction of realistic string models, their low-energy effective actions and the study of their implication for particle physics and cosmology; quantization of strings in non-trivial backgrounds and the string—gauge theory correspondence.

Significant recent publications:

1. I. Antoniadis, R. Minasian, S. Theisen, P. Vanhove, *String loop corrections to the universal hypermultiplet,* hep-th/0307268

2. S. Groot Nibbelink, H.P. Nilles, M. Olechowski, *Instabilities of bulk fields and anomalies on orbifolds,* Nucl.Phys.**B640** (2002) 171, hep-th/0205012

B3.1.3 Node Barcelona

The node consists of the research group of the University of Barcelona and will be supported by a group of the University of Valencia.

Key scientific staff:

From **Barcelona:**
Joaquim Gomis: Professor ; **scientist in charge**; supergravity, branes; 60%
Roberto Emparan: Research Professor ICREA; black holes, branes, 60%
Josep Maria Pons: Associate Professor; supergravity, symmetries of strings; 60%
Jorge Russo: Research Professor ICREA; supergravity, black holes, cosmology; 60%
Paul Townsend: Professor, ICREA and Cambridge, branes, cosmology; 50%

From **Valencia:**
José A. de Azcárraga: Professor; branes; 60%
José Navarro-Salas: Associate Professor; AdS/CFT, black holes; 60%
José M. Izquierdo: Associate Professor, University of Valladolid, branes 60%
María A. Lledó: Researcher; gauged supergravities, non-commutative geometry; 60%

The groups of **Barcelona** and **Valencia** have been active in string-M-theory and its symmetries, branes, supergravity, noncommutative field theories and cosmology. Exact solutions of string theory in a plane wave background were found. Supersymmetry algebras and enlarged superspaces were studied. Supergravity dual of gauge theories with less than maximal supersymmetry were constructed. There are successful collaborations with Austin (USA), Cambridge, Frascati, Leuven, Milano, Padova, Paris and Torino groups. The specific **areas of current research** are

- Non perturbative gauge theories and gauged supergravities (Barcelona, Valencia)
- Non-perturbative dynamics of string and M-theory (Barcelona, Valencia)
- Symmetries of String theory. Supersymmetry algebras and BPS states (Barcelona, Valencia)

The **future goals** include problems in string theory and cosmology, non-commutative geometry, models of tachyon condensation, K-theory analysis of branes, black holes in string theory and consequences of AdS/CFT holography.
Significant recent publications:

1. J. Russo and A. Tseytlin, *On solvable models of type 2B superstring in NS-NS and RR plane wave backgrounds*, JHEP **0204** (2002) 021, `hep-th/0202179`.
2. Igor A. Bandos, Jose A. de Azcarraga, Jose M. Izquierdo, Jerzy Lukierski *BPS states in M-theory and twistorial constituents*, Phys.Rev.Lett. **86** (2001) 4451, tt-hep-th/0101113.

B3.1.4 Node Madrid

The node consists of the research group of the Institute of Theoretical Physics UAM/CSIC in Madrid and will be supported by groups of the Universidad De Santiago de Compostela and the Universidad de Oviedo.

Key scientific staff:

From **Madrid:**
Cesar Gómez: Profesor de Investigacion (CSIC); **scientist in charge**; Quantum Field Theory, Quantum Gravity; 50%
Enrique Alvarez: Catedrático Universidad (UAM); Quantum Gravity, AdS/CFT; 50%
Luis Ibáñez: Catedrático Universidad (UAM); String model building; 40%
Tomas Ortín: Científico Titular (CSIC); Supergravity; 50%
Angel Uranga: Cientifico Titular (CSIC); String model building; 50%
Esperanza López: Ramón y Cajal Fellow; Branes, non commutative geometry; 40%
Karl Landsteiner: Ramón y Cajal Fellow; Branes, non commutative geometry; 40%

From **Universidad De Santiago de Compostela** and from **Universidad de Oviedo:**
Alfonso Ramallo: Catedrático Universidad; D-branes; 50%
José F. Barbón: Profesor Titular Universidad; non-commutative geometry; 40%
Javier Mas: Profesor Titular Universidad; Quantum field theory; 40%
Yolanda Lozano: Profesor Titular Universidad; D-branes; 50%

Members of the **Madrid** group have significantly contributed to the discovery of string duality symmetries (with the Berlin group); they have active research in D-brane dynamics, model building and effective action, and AdS/CFT and non-commutative geometry. The **Santiago** and **Oviedo** groups actively research on dynamics of D-brane and their role in string duality and holography. There are successful collaborations with the Berlin, Bruxelles, Groningen groups. The specific **areas of current research** are

- String Phenomenology and model building
- Supergravity
- Non Commutative Quantum Field Theory
- D-Brane dynamics in String Theory
- Gravity duals of Quantum Field Theory

The **future goals** include the understanding of phenomenologically realistic models in string theory, non perturbative dynamics of gauge theories and gravity duals, and D-brane dynamics in backgrounds with low supersymmetry.
Significant recent publications:

1. G. Aldazabal, S. Franco, L. E. Ibáñez, R. Rabadán, A. M. Uranga, *$D = 4$ chiral string compactifications from intersecting branes*, J. Math. Phys. 42 (2001) 3103.
2. S. R. Das, C. Gomez, S.-J. Rey, *Penrose limit, spontaneous symmetry breaking and holography in pp-wave background*, Phys. Rev. D66 (2002) 046002

B3.1.5 Node Bures-sur-Yvette

The node consists of the research group at IHES in Bures-sur-Yvette and will be supported by the group at the Ecole Polytechnique in Palaiseau.

Key scientific staff:

From **Bures-sur-Yvette:**
Nikita Nekrasov: Permanent professor; **scientist in charge**; susy theories; 60%
Thibault Damour: Permanent professor; string cosmology, infinite symmetries; 50%
Alain Connes: Permanent professor; non-commutative geometry; 30%
Mike Douglas: Visiting professor; string theory; 25%
Maxim Kontsevich: Permanent professor; mirror symmetry, NC geometry; 30%

From **Ecole Polytechnique:**
Elias Kiritsis: DR2; branes, string theory, string cosmology; 30%
Ruben Minasian: CR1; D-branes, string geometry; 50%
Herve Partouche: CR1; D-branes, string compactifications; 40%
Marios Petropoulos: CR1; D-branes, string compactifications; 40%

The expertise of the groups covers the general framework of M/string theory, including (super)gravity, supersymmetric theories, super- and topological strings. The group at **IHES** made outstanding contributions to string cosmology, non-commutative geometry in QFT and Matrix models and to supersymmetric field theory. The **Ecole Polytechnique** group has made outstanding contributions to string compactification and model building, the study of string perturbation theory, non-perturbative calculations and the D-brane instanton calculus, the systematic study of type-I, M theory vacua with supersymmetry breaking and string/brane cosmology. There are successful collaborations with the ENS, Potsdam, Leuven, Bruxelles, Jussieu and Dublin groups within the RTN network. The specific **areas of current research** are

- Chaos in the early cosmology and hyperbolic symmetry algebras (IHES)
- $\mathcal{N} = 1, 2$ susy theories, mathematical and physical applications (IHES)
- String cosmology (IHES, Ecole Polytechnique)
- M-theory compactifications on singular backgrounds and anomalies (Ecole Polytechnique)
- Orientifolds and associated mechanisms of supersymmetry breaking (Ecole Polytechnique)
- AdS/CFT correspondence (Ecole Polytechnique)
- Open and closed Conformal Field Theories (IHES, Ecole Polytechnique)

The **future goals** include the understanding of the hidden infinite symmetries of M theory, like E_{10} algebra; applications of the exact solutions of the supersymmetric field theories to the cosmological scenarios; exploration of string/gauge duality; in construction of the standard model using D-branes; understanding of holography in general backgrounds; study of string and brane cosmology; study of novel realizations of four-dimensional gravity.

Significant recent publications:

1. N. Nekrasov, *Seiberg-Witten prepotential from instanton counting*, hep-th/0206161.
2. E. Kiritsis, C. Kounnas, P.M. Petropoulos, J. Rizos. *Five-brane configurations without a strong coupling regime* Nucl.Phys.B652:165-195,2003; hep-th/0204201

B3.1.6 Node Paris

The node consists of the research group at the Laboratoire de Physique Théorique of the Ecole Normale Supérieure (LPT-ENS) and will be supported by the group of the Service de Physique Théorique CEA/Saclay (SPhT).

Key scientific staff

From **LPT-ENS:**

Costas Kounnas; DR1; **Scientist-in-charge**; M/string/brane theories and cosmology; 60%
Adel Bilal; DR2; M- and string theories; matrix models; 40%
Eugène Cremmer; DR1: supergravity, M-theory; 60%
Pierre Fayet; DR1; supersymmetry; cosmology; 30%
Frank Ferrari; CR1 matrix models, supersymmetry; 40%
Jean Iliopoulos; DRCE; supersymmetry, quantum gravity, cosmology; 60%
Bernard Julia; DR1; M- and string theory; 40%
Volodya Kazakov; Full Professor; matrix models, conformal theories; 40%

From **SPhT-CEA:**

Denis Bernard; DR2; applied conformal field theories; 50%
Francois David; DR1; matrix models, field theory; 60%
Bertrand Eynard; Chercheur-CEA; matrix models, field theory 50%
Ivan Kostov; DR2; matrix models, conformal theories; 50%
Pierre Vanhove; Chercheur-CEA; M- and string theories; 60%
Volker Schomerus; Chercheur-CEA; M- and string theories, conformal theories; 60%

The expertise covers the general framework of M- and string theory, supergravity and supersymmetric theories, supersymmetry breaking, conformal field theories and matrix models. The group at **ENS** made outstanding contributions to string constructions, supergravity theories and to the standard model physics and cosmology. The **SPhT-CEA** group has made outstanding contributions to conformal field theory, matrix models and applications. There is also a long and constant tradition in the Paris group of "European Collaborations" especially with Berlin, Bonn, Brussels, the Italian and Greek nodes, Leuven, London, Potsdam, Trieste, Zurich and Neuchâtel. The specific **areas of current research** are

- String constructions, string/brane dualities, string thermodynamics and (non-) perturbative supersymmetry breaking in string/brane theories.
- M and string theory compactifications.
- Boundary conformal field theories and matrix models.
- Strings and branes in non-trivial gravitational backgrounds.
- Standard versus string/brane cosmology and implications.

The **future goals** include extensive and systematic study of strings in non-trivial time-dependent backgrounds and their cosmological applications, non-perturbative properties of string /brane theories, M-and string theory compactifications, conformal field theories and matrix models.

Significant recent publications:

1. L. Cornalba, M.S. Costa and C. Kounnas, *A Resolution of the Cosmological Singularity with Orientifolds* Nucl.Phys. **B 637**(2002) 378; hep-th/0204261.

2. S. Yu Alexandrov, V. A. Kazakov and I. K. Kostov, *Time Dependent Backgrounds of 2-D String Theory*, Nucl.Phys. **B 640** (2002) 119; hep-th/0205079.

B3.1.7 Node Copenhagen

The node consists of the research group of the Nordisk Institut for Teoretisk Fysik (NORDITA) and the Niels Bohr Institute (NBI) of the University of Copenhagen and will be supported by a group at the University of Iceland in Reykjavík.

Key scientific staff:

From **Copenhagen:**
Paolo Di Vecchia: Professor (NORDITA); **scientist in charge**; D-branes, gauge theories; 50%
Jan Ambjorn: Professor (NBI); non-commutative geometry, matrix models; 40%
Jens Lyng Petersen: Professor (NBI); AdS/CFT; 10%
Niels Obers: Professor (NBI); M-theory, duality symmetries; 50%
Poul Olesen: Professor (NBI); gauge theories; 30%
Charlotte Fløe Kristjansen: Assistant Professor (NORDITA); AdS/CFT, matrix theory; 50%
Troels Harmark: Assistant Professor (NBI); black holes, non-commutative geometry; 50%

From **Reykjavík:**
Larus Thorlacius: Professor; String theory, quantum gravity, quantum field theory; 50%
Thordur Jonsson: Research Professor; quantum field theory, non-commutative geometry; 50%

Members of the group in **Copenhagen** are among the founders of early string theory. Furthermore, the group made very basic contributions to D-brane dynamics, relation between D-branes and gauge theories, AdS/CFT correspondence and non-commutative geometry. The group in **Reykjavík** made very important contributions to quantum aspects of black holes, quantum cosmology, boundary conformal field theory, string thermodynamics, and non-commutative geometry. There are successful collaborations with the Torino, Ecole Polytechnique and Napoli groups. The specific **areas of current research** are

- Matrix models and 2-dimensional quantum gravity
- String duality symmetries and BPS spectrum in string and M-theory
- Supersymmetric gauge theories and Gravity duals of Quantum Field Theory

The **future goals** contain studies of less supersymmetric, non-conformal gauge theories, time dependent string backgrounds like S-branes, the description of more general BMN operators and the development of analytic techniques for the study of black holes on spaces with non-trivial topology. **Significant recent publications:**

1. P. Di Vecchia, A. Lerda and P. Merlatti, *N=1 and N=2 super Yang-Mills theories from wrapped branes,* Nucl. Phys. **B646** (2002) 43, hep-th/0205204.
2. R.A. Janik and N.A. Obers, *SO(N) superpotential, Seiberg-Witten curves and loop equations,* Phys. Lett. **B553** (2003) 309, hep-th/0212069.

B3.1.8 Node Dublin

The node consists of the research group at Trinity College, Dublin and University College, Dublin.

Key scientific staff:
Samson Shatashvili: Full Professor, University chair of Natural Philosophy, Trinity College Dublin; **Scientist in charge**; string theory, super-symmetric gauge theories; 50%
Danny Birmingham: senior lecturer, University College Dublin; black holes, AdS/CFT, topological gauge theories 40%
Conor Houghton: lecturer, Trinity College; monopoles and Skyrmions; 40%
Siddhartha Sen: associate professor emeritus, Trinity College; 40%

The members of the group have made a significant contributions in the past in quantum field theory, string theory, solitons, cosmology and black holes, matrix theory, statistical physics, etc. There are successful collaborations with the IHES group in Bures-Sur-Yvette where Samson Shatashvili is a Louis Michel chair.

The specific **areas of current research** are

- String Field Theory and Tachyon condensation
- Super-symmetric gauge theories
- Black holes
- D-branes and derived categories

The **future goals** are to describe the fundamental symmetries underlying string theory, to understand how closed strings appear from open strings in open string field theory and gauge-theory, conversely - to understand the vacuum structure of confining theories using their relation with string theory and to understand gravitating objects within this framework and resolve (curvature) singularities in black holes and cosmology.

Significant recent publications:

1. Anton A. Gerasimov, Samson L. Shatashvili, On Exact Tachyon Potential in Open String Field Theory, JHEP 0010 (2000) 034

2. G. Moore, N. Nekrasov, S. Shatashvili, D-particle bound states and generalized instantons, Commun.Math.Phys. 209 (2000) 77-95

B3.1.9 Node Frascati

The node consists of the research group of the INFN National Laboratories at Frascati and will be supported by groups of Napoli University, Padova University and SISSA in Trieste.

Key scientific staff:
From **Frascati:**
Sergio Ferrara: Full professor; **scientist in charge**; supergravity, AdS/CFT, flux compactifications, non-commutative superspaces; 50%
Stefano Bellucci: INFN researcher; AdS/CFT, non-commutative field theory and mechanics; partial supersymmetry breaking; 50%
Fabrizio Palumbo: Full professor; gauge theories, non-perturbative phenomena in field theory; 50%
From **Napoli:**
Raffaele Marotta: Research associate; String model building, boundary state formalism; 40%
Renato Musto: Full professor; brane dynamics, quantum field theory; 30%
Francesco Nicodemi: Full professor; brane dynamics, string scattering amplitudes, non-perturbative phenomena; 50%
Roberto Pettorino: Full professor; general relativity, black holes; 30%
Franco Pezzella: Research associate; supersymmetry, tachyon condensation, brane effective actions; 40%
From **Padova:**
Antonio Bassetto: full professor; non commutative gauge theories; 30%
Kurt Lechner:associate professor; anomalies for extended objects; 50%
Pieralberto Marchetti: associate professor; monopoles and extended objects 40%
Marco Matone: reserch associate; matrix models and Liouville theory 50%
Paolo Pasti: associate professor; branes, non commutative geometry 50%
Dmitri Sorokin: researcher INFN; brane physics, higher spin theory 50%
Mario Tonin: full professor; quantization of superstrings, branes 50%.

From **Trieste:**
Loriano Bonora: full professor; string field theory, non-commutative geometry; 50%
Roberto Iengo: full professor; string loop effects, string massive state properties; 50%
Marco Serone: research associate; string compactification, SUSY breaking mechanisms; 50%
Matteo Bertolini: research associate; D-brane physics, gauge theory; 50%

The group in **Frascati** made important contributions to gauged supergravity and duality symmetry, supersymmetry algebras in diverse dimensions, super Higgs effect, supersymmetric theories in non-commutative superspaces, classification of operators in the AdS/CFT correspondence, supergravity interpretation of flux compactification, supersymmetric Born-Infeld actions, gauge theories in non-compact spaces. Members of the **Napoli** group have made important contributions to the construction of string scattering amplitudes also to study tachyon condensation; the boundary states formalism; the study of fractional branes; the gauge/gravity duality to study non-perturbative aspects of gauge theories; the analysis of non-conformal field theories from their bulk duals, generalizing the AdS/CFT correspondence. The group in **Padova** has a long expertise on the QFT of monopoles and dyons, anomalies in QFT, Seiberg-Witten theory, brane physics, duality symmetries, and superspace formulation of supergravity theories. Members of this group formulated and developed the superembedding approach for superparticles, superstrings and superbranes. The local expertise of the group in **Trieste** contains string field theory, non-commutative field theory, properties of string excited states, many-loop computations in string theory, D-brane dynamics, supersymmetry breaking in string theory, anomalies in string theory, discrete gravity. There are successful collaborations with the Copenhagen, Torino, Bruxelles, Valencia and Zürich groups. The specific **areas of current research** are

- AdS/CFT correspondence (Frascati, Napoli)
- Matrix models, supersymmetric Yang-Mills theory and supergravity (Frascati, Padova)
- Non-commutative supersymmetric field theory (Frascati)
- Spontaneous supersymmetry breaking (Frascati, Trieste)
- Non-perturbative aspects of gauge theories (Frascati)
- Boundary states formalism (Napoli)
- Gauge/gravity duality (Napoli)
- Brane physics (Frascati, Padova)
- Theory of higher spin fields (Padova)
- Decay of massive string states (Trieste)

The **future goals** include supersymmetry breaking in string and M-theory compactification; the relation of non-commutative supersymmetric theories with strings in different backgrounds; effective actions of bulk supergravity coupled to branes in the presence of fluxes; the use of gauge/gravity duality to get insights into non perturbative phenomena such as confinement and chiral symmetry breaking; the further extension of the AdS/CFT correspondence to non conformal cases; the study of the tachyon potential through off-shell tachyon amplitudes; the matrix model conjecture of Dijkgraaf-Vafa; the pure spinor approach of Berkovits to the covariant quantization of superstrings; the theory of higher spin fields; the non-Abelian DBI-action of D-branes; the anomaly cancellation in systems of p-branes; the holographic principle; quantum field theories on non-commutative spaces; string field theory and its interplay with non-commutative dynamics; the mechanisms of string compactification and supersymmetry breaking; the properties of string excited states.

Significant recent publications:

1. S. Ferrara, M.A. Lledó, *Some Aspects of Deformations of Supersymmetric Field Theories,* JHEP **0005** (2000) 008, hep-th/0002084.
2. L. Andrianopoli, R. D'Auria, S. Ferrara, M.A. Lledó, *Gauging of Flat Groups in Four Dimensional Supergravity,* JHEP **0207** (2002) 010, hep-th/0203206.

B3.1.10 Node Torino

The node consists of the research group at the Università di Torino and will be supported by a group at the Politecnico di Torino, by a group at the Università "*Amedeo Avogadro*" in Alessandria, by a group at the Università di Milano (Milano I), and by a group at the Università di Milano-Bicocca (Milano II).

Key scientific staff:

From **Torino University:**
Pietro Frè: Full professor; **scientist in charge**; supergravity and M/theory; 50%
Marco Billò: Researcher; strings, D-branes and supergravity; 50%
Anna Ceresole: INFN First Researcher; supergravity and M/theory; 50%
Alessandro D'Adda: INFN Director of Research; gauge theories and matrix models; 30%
Marialuisa Frau: Researcher; strings, D-branes and gauge theories; 50%
Igor Pesando: Researcher; strings and D-branes; 50%
Stefano Sciuto: Full professor; strings and non-commutative field theories; 50%

From **Torino Politecnico:**
Riccardo D'Auria: Full professor; (gauged) supergravity and M-theory; 50%
Mario Trigiante: Research associate; supergravity and M-theory; 50%

From **Alessandria:**
Leonardo Castellani: Full professor; supergravity and non-commutative geometry; 50%
Alberto Lerda: Full professor; strings, D-branes and gauge theories; 50%

From **Milano I:**
Dietmar Klemm: Researcher; black holes and AdS/CFT correspondence; 50%
Mario Pernici: INFN First Researcher; field theory, supergravity; 30%
Daniela Zanon: Full professor; branes and supersymmetric gauge theories; 50%

From **Milano II:**
Luciano Girardello: Full professor; supergravity, strings and gauge theories; 50%
Silvia Penati: Researcher; non-commutative field theories and gauge theories; 50%
Alberto Zaffaroni: Associate professor; strings, branes and AdS/CFT; 50%

In the past, members of the **Torino** and **Milano** groups contributed in a significant way to the original formulation of string theory and supergravity. More recently, the various groups of the Torino node have obtained important results in the study of the AdS/CFT correspondence and renormalization group flows (**Milano II**), in the study of D-brane dynamics through boundary states (**Torino, Alessandria**), and of the relation between D-branes and gauge theories known as gauge/gravity correspondence (**Torino, Alessandria, Milano II**). Very significant results have been obtained also in the study of string and M/theory compactifications in diverse backgrounds with or without fluxes (**Torino, Torino Politecnico, Milano I**), in the analysis of the non-perturbative properties of supersymmetric gauge theories by means of perturbative methods and matrix models (**Milano I**) and in the study of field theories in non commutative geometries. (**Milano II**). There are several successful collaborations with the groups in Berlin, Copenhagen, Frascati, Leuven, Paris and Utrecht. The specific **areas of current research** are

- Gauged supergravity and flux compactifications
- D-branes and gauge/(super)gravity correspondence

- Perturbative and non-perturbative properties of supersymmetric gauge theories in terms of string and brane configurations
- Non-(anti)commutative supersymmetric field theories
- Mechanisms for supersymmetry breaking
- Cosmological backgrounds and compactifications of string/M theory

The **future goals** include the study of the gauge/(super)gravity correspondence in cases without conformal invariance and reduced supersymmetry, further analysis of gauged supergravities, flux compactifications and mechanisms for supersymmetry breaking, the study of the non-perturbative vacuum structure of supersymmetric gauge theories by means of matrix models and branes beyond the planar limit and the calculation of gravitational corrections in supersymmetric gauge models with perturbation theory, the study of the relation between non-(anti)commutative field theories and string theory in different backgrounds, and the study of time-dependent compactifications of string and M-theory.

Significant recent publications:

1. L. Girardello, M. Petrini, M. Porrati and A. Zaffaroni, *The supergravity dual of $N = 1$ super Yang-Mills theory*, Nucl. Phys. B **569** (2000) 451 [hep-th/9909047].
2. R. Dijkgraaf, M.T. Grisaru, C.S. Lam, C. Vafa and D. Zanon, *Perturbative computation of glueball superpotentials*, HUPT-02-A056 (Nov 2002) [hep-th/0211017].

B3.1.11 Node Leuven

The node consists of the research group at the Katholieke Universiteit Leuven and will be supported by a group at the Vrije Universiteit Brussel and a group at the Université Libre de Bruxelles.

Key scientific staff:
From **Leuven:**
Antoine Van Proeyen: Full professor; **scientist in charge**; (gauged) supergravity; 50%
Walter Troost: Full professor; branes; 50%
From **Brussel:**
Alexander Sevrin: Full professor; string and brane effective actions, branes; 50%
From **Bruxelles:**
Marc Henneaux: Full professor; cosmology, symmetries, black holes; 50%
François Englert: Professor emeritus; branes, black holes; 30%
Glenn Barnich: Tenured FNRS researcher; symmetries; 40%
Laurent Houart: Tenured FNRS researcher; black holes, branes; 40%

The group in **Leuven** pioneered the formulation of supergravity theories and gauged supergravities. It developed the concept of *special geometry* which is central in various duality symmetries between seemingly different string theories. The group in **Brussel** played and plays a leading role in the construction of the non-abelian D-brane effective action. The group in **Bruxelles** made fundamental contributions to our present understanding of black holes and is very active in cosmology and symmetries.

All Belgian groups have expertise in superalgebras, infinite dimensional Lie algebras of various kinds, superconformal algebras and their applications, Batalin-Vilkovisky quantization, theoretical aspects of black holes. The Belgian node has intensive scientific collaborations with the groups at Barcelona, Berlin, Groningen, Imperial College, Milano, Oviedo, Paris, Utrecht. The specific **areas of current research** are

- Gauged supergravity theories and their applications.
- D-brane effective actions.
- Infinite dimensional symmetries in gravity/string theory.

The **future goals** include the completion of the map of supergravity theories together with cataloging (the properties of) their solutions; the construction of the full non-abelian D-brane effective action and the study of its applications; the study of the infinite-dimensional symmetry of the maximally oxidized theories including gravity; the study of consistent interactions for massless higher spin fields in the context of string field theory together with the dualities involving these fields.

Significant recent publications:

1. E. Bergshoeff, R. Kallosh, A. Van Proeyen, *Supersymmetry in Singular Spaces*, JHEP **10** (2000) 033, `hep-th/0007044`.

2. T. Damour, M. Henneaux, B. Julia, H. Nicolai, *Hyperbolic Kac-Moody algebras and chaos in Kaluza-Klein models*, Phys.Lett. **B509** (2001) 323, `hep-th/0103094`.

B3.1.12 Node London

This node consists of the research group at Imperial College London and will be supported by a group in Edinburgh.

Key scientific staff:

From **Imperial College London:**
Kellogg Stelle: Full professor; **scientist in charge**; supergravity, super membranes, M-theory; 60%
Chris Hull: Full professor; brane solutions, string duality, plane waves; 40%
Jerome Gauntlett: Full professor; calibrated branes, compactifications; 40%
Arkady Tseytlin: Full professor; brane solutions, AdS/CFT correspondence; 50%
Dan Waldram: Lecturer; string and M-theory compactifications; 40%

From **Edinburgh:**
José Figueroa-O'Farrill: Reader; supersymmetric backgrounds, D-branes; 50%
Harry Braden: Reader; integrability, matrix models and gauge theory; 40%
Richard Szabo: Reader; non-commutative geometry; 40%

The group in **London** has decades of experience in General Relativity, supergravity and superstrings, cosmology and the foundations of quantum theory. Its basic results include key developments in supergravity, the rôle of supersymmetric branes in M-theory, and the non-perturbative structure of string and M-theory. The arrival of three new members of the string group from Queen Mary College make Imperial one of the strongest centers of string theory and supergravity.

The group in **Edinburgh** has worked extensively in conformal field theory, integrability and its applications to string theory, topological and geometrical aspects of quantum field theory and non-commutative geometry.

There are successful ongoing collaborations with the Barcelona, Frascati, Leuven, Paris and Utrecht groups. The specific **areas of current research** are

- M-theory compactifications, Flux compactifications, M-theory cosmology (London)
- AdS/CFT correspondence and plane wave solutions (London, Edinburgh)
- Non-commutative geometry (Edinburgh)

The **future goals** include the development of techniques for the classification of supersymmetric solutions, the rôle of hidden symmetries in string and M-theory, string aspects of AdS/CFT duality, in particular on backgrounds with fluxes and on RR backgrounds away from the plane-wave limit, vacuum structure and tachyon stabilization, string and M-theory models for cosmology.
Significant recent publications:

1. M. Blau, J. Figueroa-O'Farrill, C.M. Hull and G. Papadopoulos, "A new maximally supersymmetric background of IIB superstring theory," JHEP **0201**, 047 (2002) [arXiv:hep-th/0110242].
2. J.G. Russo, A.A. Tseytlin, "On Solvable Models of Type IIB Superstring in NS-NS and RR Plane Wave Backgrounds," JHEP 0204:021,2002. [arXiv:hep-th/0202179]

B3.1.13 Node Neuchatel

The node consists of the research group at Neuchâtel University, supplemented by a group at the ETH, Zürich.

Key scientific staff:

From **Neuchâtel:**
Jean-Pierre Derendinger: full professor; **scientist in charge**; strings and M-theory compactification, effective supergravity, supersymmetry breaking; 50%.
Matthias Blau: full professor; strings and M-theory: symmetries, time-dependent backgrounds and singularities; 35%.

From **Zürich:**
Matthias Gaberdiel: associate professor; D-branes, boundary states; 40%.
Giovanni Felder: full professor; conformal field theory, boundary states; 15%.
Jürg Fröhlich: full professor; conformal field theory, boundary states, non-commutative geometry; 15%.
Costas Bachas: full professor (part-time); string theory, D-branes; 20%.

The Neuchâtel group has made contributions to the study of string compactifications (symmetries, anomalies and supersymmetry), to the discovery of maximally supersymmetric solutions to string theories and to the study of the phase structure of duality-related string theories. There have been recent successful collaborations with in particular Paris (ENS, Polytechnique) and Patras.

The group in Zürich has a strong background in conformal field theory (CFT), and members have pioneered the use of CFT methods for the construction and description of D-branes in string theory. It also has expertise in non-commutative geometry and infinite-dimensional Lie algebras. There have been successful collaborations with ENS and Bures-sur-Yvette as well as Berlin.

The specific **areas of current research** are

- D-branes in plane-wave backgrounds
- Time-dependent D-brane and string backgrounds
- Supersymmetry breaking in non-factorized (warped) and wall-like backgrounds.

The **future goals** include a more detailed understanding of time-dependent decay processes in string theory, in particular for unstable D-brane configurations; and an analysis of string theory in pp-wave backgrounds in terms of their integrable world-sheet theories. Secondly, efforts towards a better understanding of the supersymmetry content of string solutions (supersymmetry breaking in realistic theories) will be made.

Significant recent publications:

1. M. Blau, J. Figueroa-O'Farrill, C. Hull, G. Papadopoulos, *Penrose limits and maximal supersymmetry*, Class. Quant. Grav. **19** (2002) L87-L95, hep-th/0205183.

2. O. Bergman, M.R. Gaberdiel, M.B. Green, *D-brane interactions in type IIB plane-wave background*, JHEP **0303** (2003) 002, hep-th/0205183.

B3.1.14 Node Patras

The node consists of the research group at the University of Patras and will be supported by a group at the National Technical University of Athens.

Key scientific staff:

From **Patras**:
Ioannis Bakas: Full professor; **scientist in charge**; symmetries of string theory, integrable structures, supergravity, higher spin fields, solitons and instantons; 50%
Konstadinos Sfetsos: Associate professor; supergravity, AdS/CFT, black holes, branes, manifolds of special holonomy; 50%

From **Athens**:
Alexandros Kehagias: Assistant professor; supergravity, manifolds of special holonomy, AdS/CFT, brane worlds, cosmology; 50%

In the past, members of the **Patras** group have made important contributions to the discovery of infinite dimensional symmetries in string theory, string duality symmetries, the construction of conformal field theories, pp-wave solutions, black hole and branes within the AdS/CFT correspondence, the classification of domain wall solutions of gauged supergravities, and compactifications of M-theory on exceptional holonomy manifolds. The group in **Athens** has contributed to the AdS/CFT correspondence, the geometry of special holonomy manifolds, brane world models and string cosmology. There are successful collaborations with Neuchatel, Paris, Frascati and Torino, but close ties also exist with scientists from other groups of the network. The specific **areas of current research** are

- Infinite dimensional symmetries of string theory
- Strings on pp-waves and AdS/CFT correspondence
- M-theory on manifolds with exceptional holonomy
- Renormalization group flows and tachyon condensation
- String cosmology

The **future goals** include string quantization on $AdS \times S$ backgrounds, construction of new G_2-holonomy manifolds, study of cosmological and other dynamical solutions of string theory, and the investigation of higher spin fields in the tensionless limit of strings.

Significant recent publications:

1. I. Bakas, *Renormalization group flows and continual Lie algebras*, JHEP 08(2003)013, hep-th/0307154
2. A. Kehagias and E. Kiritsis, *Mirage cosmology*, JHEP **9911** (1999) 022, hep-th/9910174

B3.1.15 Node Sofia

The node consists of a research group from the Laboratory "Theory of Elementary Particles" at the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences in Sofia (Bulgaria) and will be supported by a group from the Faculty of Physics from the University of Craiova (Romania).

Key scientific staff:

From the **Institute for Nuclear Research and Nuclear Energy, Sofia:**
Ivan Todorov: Full professor; **scientist in charge**; conformal field theory; 40%
Vladimir Dobrev : Full professor; conformal (super-)symmetry, quantum groups; 60%
Alexander Ganchev: Assoc. professor; CFT, tensor categories, fusion rules; 40%
Emil Nissimov: Assoc. professor; strings and Dp-branes, integrable systems; 60%
Svetlana Pacheva: Assoc. professor; strings and Dp-branes, integrable systems; 60%
Valentina Petkova: Assoc. professor; CFT including boundary CFT, fusion rules; 40%
Marian Stanishkov: Assoc. professor; conformal field theory and integrable systems; 40%

From **University of Craiova:**
Constantin Bizdadea: Full professor; gauge theories and BRST symmetry; 60%
Solange-Odile Saliu: Associate professor; gauge theories and BRST symmetry; 60%

Members of the **Sofia** group contributed in a significant way to the general structure of two- and higher-dimensional conformal field theory, understanding of WZW fusion rules and the study of fractional level WZW models, quantum groups and their representations, the systematic formulation of super-Poincare covariant quantization for Green-Schwarz superstrings. In the past, members of the **Craiova** group have obtained results in BRST quantization of field theories with second-class constraints, irreducible BRST quantization of reducible gauge theories and interactions in gauge theories. There are several successful ongoing collaborations of the **Sofia** group with members of the proposed network such as IHES, Saclay and Trieste. Closer contacts are being developed with the group at Patras.
The specific areas of **current research** and **future goals** are:

- Global conformal invariance, rationality, theory of vertex algebras and modular properties in 4 and higher dimensions;
- Classification of UIR's of higher-dimensional ($6 < D \leq 12$) superconformal symmetry and study of deformations of AdS quantum group $SO_q(3,2)$;
- Modified string and Dp-brane models with dynamical tension and their applications in brane-world scenarios and cosmology;
- Study of K-theory of tensor categories, higher groups and higher gauge theories;
- Interactions in BF and mixed symmetry-type gauge theories.

Significant recent papers:

1. N.M. Nikolov and I.T. Todorov, *Rationality of conformally invariant local correlation functions on compactified Minkowsi space*, Commun. Math. Phys. **218** (2001) 417, [hep-th/0009004].
2. C. Bizdadea, E. M. Cioroianu, I. Negru and S. O. Saliu, *Lagrangian interactions within a special class of covariant mixed-symmetry type tensor gauge fields*, Eur. Phys. J. **C27** (2003) 457 [hep-th/0211158].

B3.1.16 Node Utrecht

The node consists of the research group at Utrecht university and will be supported by the group of Groningen university.

Key scientific staff:

From **Utrecht:**
Bernard de Wit: Full professor; **scientist in charge**; supergravity, black holes; 50%
Stefan Vandoren: Assistant professor; supergravity, instantons; 50%
Gerard 't Hooft: Full Professor; quantum gravity, black holes; 20%
Renate Loll: Associate professor; quantum gravity; 20%

From **Groningen:**
E. Bergshoeff: Full professor; supergravity, branes and dualities; 50%
M. de Roo: Full professor; string effective actions, cosmology; 50%

Members of the groups in **Utrecht** and **Groningen** pioneered the formulation of supergravity theories, supermembrane theories, and the holographic principle in quantum gravity. They have played an important role in constructing supersymmetric brane-actions and in studying instanton effects in field and string theory. There are successful collaborations with the groups in Berlin, Bonn, Copenhagen, Frascati, Leuven, London, Madrid and Torino.

Specific **areas of current research** are

- Black holes and area law corrections
- Holography and AdS/CFT dualities
- Gauged supergravities and de Sitter solutions
- Brane world models
- Nonperturbative string theory
- D-brane actions
- Matrix model approach to string and quantum gravity

The **future goals** of **Utrecht** and **Groningen** include the investigation of black holes, branes, applications of gauged supergravities, and the study of non-perturbative effects in field and string theory. We also intend to further explore on how to get cosmological models out of string theory, and on the relation between matrix models and N=1 supersymmetric field theories. Furthermore, we are planning to answer the question whether or not a supersymmetric extension of the Randall-Sundrum scenario can be formulated.

Significant recent publications:

1. B. de Wit, B. Kleijn and S. Vandoren, *Superconformal hypermultiplets*, Nucl. Phys. **B568** (2000) 475, `hep-th/9909228`.

2. E.A. Bergshoeff, M. de Roo, T.C. de Wit, E. Eyras and S. Panda, *T-duality and actions for non-BPS D-branes*, JHEP 0005:009, 2000, `hep-th/0003221`.

B3.2. Intensity and quality of networking

The yearly school (during the winter) and workshop (during the summer) are central to the quality of networking.

School: Every year the network agrees on a list of topics which are not generally mastered by all of the nodes in the network and which are nonetheless essential for the success of the research programme. On the basis of this, we look for leading experts in those subjects (not necessarily members of our network) who can present during one week a set of advanced lectures aimed at senior graduate students, post-doctoral fellows and staff members. This school has grown to be the most important European school on advanced topics in string theory, supergravity and related topics as can be seen from the number of people attending: Leuven 1999: 105, Torino 2000: 104, Paris 2001: 144, Utrecht 2002: 117, Torino 2003: 168.

Workshop: The widely attended (e.g. Corfu 2001: 137, Leuven 2002: 125, Copenhagen 2003: 149) yearly workshop provides the young researchers employed by the network with a forum where they can present their results. In addition, every day starts with a 90 minute lecture given by a leading expert (not necessarily belonging to the network) of a recent and important new development in our field which might be relevant to our research programme.

These two events provide every six months a forum where a large fraction of the people participating in the network are present. Ample time for discussion is foreseen and past experience has demonstrated that numerous collaborations originate at the school or at the workshop.

As explained under section B1.4, a novel feature will be the creation of **five working groups** around each of the five main research topics of this proposal. These working groups, each led by a senior scientist, will meet on a more frequent time-scale thereby enhancing the possibilities for scientific collaborations. The functioning of the working groups will be evaluated on a six monthly basis (at the occasion of the school and the workshop).

Next to these, courses on advanced subjects relevant to the research programme are regularly organized at individual nodes. These courses are advertised network wide and attract numerous participants from other nodes thereby providing once more an occasion for discussion and starting up new collaborations.

At an individual level, the network greatly facilitates the mobility of collaborations between different nodes. Indeed, frequent visits of both junior and senior scientists to other nodes provide a powerful mechanism for collaborative research efforts. Practically, things are arranged so that the visiting scientists assume responsibility for their travel expenses while the hosting node takes care of the housing.

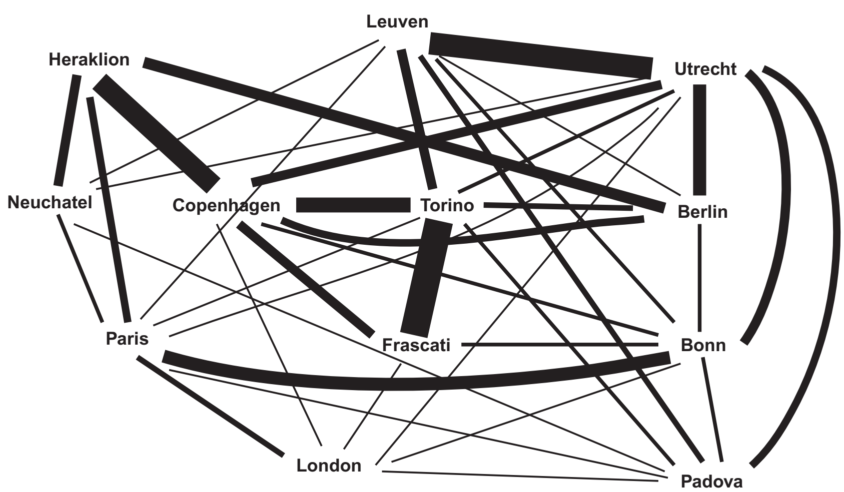
Finally, the internet has proven to be a very productive medium for the functioning of our network. Besides the rapid dissemination of new ideas and results, there are daily e-mail contacts between collaborations plus the regular network-wide e-mails providing essential information on the functioning of the network, while the young researchers set up a dedicated (password protected) web page which allows them to discuss new results in the literature, potential collaborations and so on.

From the above it is clear that the combination of both network-wide and individual activities and initiatives provides a stimulating environment both for training and for research.

The initiatives sketched above will be particularly useful for the participating groups belonging to the focus one regions (such as Patras and Potsdam) and the "new countries" (Bulgaria and Romania).

B3.3. Relevance of partnership composition

A majority of the teams involved in the present project were already participating in a fourth framework TMR network project ERB-FMRX-CT96-0045 *Quantum aspects of gauge theories, supersymmetry and unification* and are currently member of a fifth framework RTN network HPRN-CT-2000-00131, *The quantum structure of spacetime and the geometric nature of fundamental interactions*, which ends on 31/9/2004 (see also further information under section B8). A smaller subset of the teams were already participating in a third framework Science project SC*1-CT92-0789 *Gauge, Theories, applied supersymmetry and Quantum Gravity*. These networks have led to numerous collaborations between nodes. To illustrate this we show the collaborations between different nodes (each of which include the subnodes) of our fifth framework RTN. The width of the lines are proportional to the number joint publications between two nodes. The figure covers 112 eligible publications published between 1/10/2000 through 15/06/2002 (from its start through the mid-term review).



This clearly demonstrates that the proposed network can build upon numerous very active and successful collaborations. The addition of several new nodes injects substantial new expertise into the network. E.g., the Madrid group adds an important phenomenological component, Edinburgh and Bures-sur-Yvette add mastery of numerous relevant mathematical tools and so on. The inclusion of the Sofia node is again based on the scientific value of this group, but in addition will also help to integrate this team, located in a candidate country for the EU, into the European science landscape. The network intends to fully use and disseminate this new know-how. In turn, this will directly lead to new collaborations and scientific results.

Finally, we are confident that the novel initiative of having workgroups, as explained in section B1.4, centered around each of the main research topics will further enhance mutual collaborations.

B4 MANAGEMENT AND FEASIBILITY

B4.1. Proposed management and organizational structure

The proposed network will have a very transparent and efficient management and organizational structure. This structure will ensure a very smooth and efficient administration of the network. The distribution of the financial funds to the various nodes will be done by the coordinator of each university, and the distributed amounts will be based on the number of hired young researchers in each team. The local management is then done by financial officers of each university. An Amount of about 100.000 Euro is held by the coordinator for common activities, i.e. conferences, workshops and schools. The network will possess efficient methods for communication and reporting of results. For this purpose we will create a network bulletin on the world wide web, which is in general open to the public, but also contains an internal section, which is accessible for the scientists in charge only by a password.

Specifically the management structure is as follows:

a) Coordinator: He represents the network as a whole to the outside and is of course the relevant contact person to the EU commission. The coordinator supervises the general functioning of the network. The coordinator collects all relevant financial informations, and he is responsible for the financial and scientific reports to the EU.

a1) Deputy coordinator: He will assist the coordinator in all relevant issues. The nominated person in charge is **Alexander Sevrin** from Brussels.

b) Executive Board: All *scientists in charge* of the participating teams are members of the executive board. It should meet at least twice every year (during the school and during the workshop). It discusses the proposals of the coordinator. The executive board decides upon the recruitment of young researchers. It will also decide about the scientific content of the common meetings of the network and can propose new initiatives. The executive board can be supported and advised by other scientists of the network.

c) Secretaries: We nominate several secretaries, who will be concerned with some central organizational problems of the network. They will also communicate between the coordinator and the Executive Board during the entire year. Therefore they will be very important for the smooth management of the network. There will be secretaries in the following fields:

(i) Outreach: This person is responsible for the public relations affairs, such as communication of results to the public, public talks etc. The nominated person in charge is **Kellogg Stelle** from Imperial College in London.

(ii) Training of young researchers and schools: This person is responsible for the training programme and the organization of schools. The nominated person in charge is **Daniela Zanon** from Milano.

(iii) Workshops and research issues: This person will supervise and coordinate the research efforts of the network. This person will also assist the local organizers of the workshops and will be consulted by the five scientists who will organize the working groups. The nominated person in charge is **Elias Kiritsis** from Ecole Polytechnique.

(iv) Recruitment and contact person for the young researchers: This person will supervise the recruitment of the young researchers and will also be the contact person for young researchers concerning network questions. This person will also be attentive to the opportunities of women

in the recruitment process (see the plans in section B.6.3.). The nominated person in charge is **Antoine Van Proeyen** from Leuven.

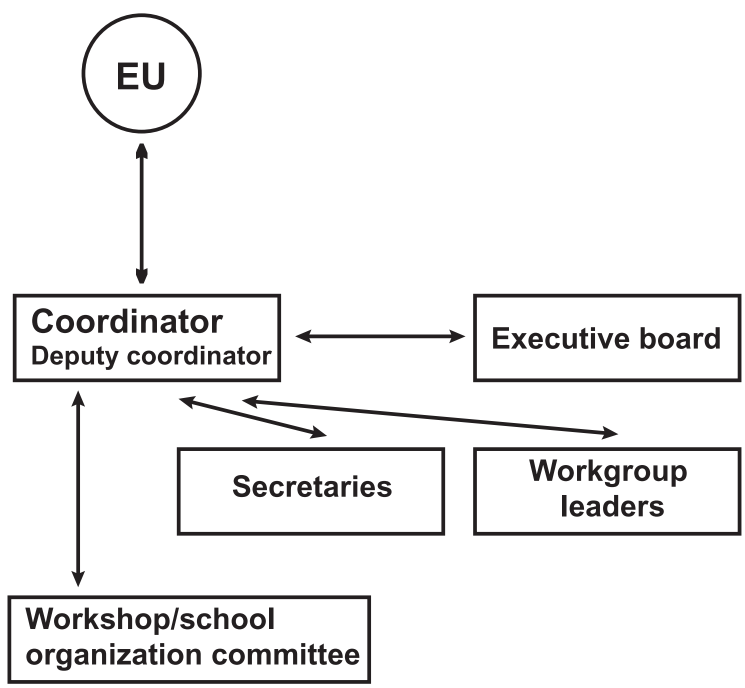
(v) Maintenance of the Web-page: This person will maintain the web-page, which includes the on-line applications of the young researchers. The nominated person in charge is **Marco Billo** from Torino.

(vi) Representative of the young researchers: He represents the young researchers in the executive board and workshop/school organization committees.

d) Working group leaders: Their role was already explained. They will assist the executive board and the Specialists in all scientific issues, and they will also organize the working groups. They will be assisted by young researchers who will be asked to write reports on the research and training progress and the foreseen activities. The nomination of the work group leaders will be done after the beginning of the network.

e) Workshop/School organization committees: These committees consist of scientists of the network, including the local organizers plus organizers of the previous meetings in order to ensure that past experience is suitably taken into account.

The whole management structure is summarized in the following diagram:



B4.2. Management know-how and experience of network coordinator

The coordinator of the proposed network, Prof. Dieter Lüst (Humboldt-University of Berlin) has demonstrated his scientific and organizational competence to conduct a large scale research grant in various instances. At an international level, he is/was the team leader (contact person) of the Berlin group in two EU networks, namely the RTN network *The Quantum structure of spacetime and the geometric nature of fundamental interactions* (HPRN-CT-2000-00131) and the TMR network *Quantum aspects of gauge theories, supersymmetry and unification* (ERBFMRXCT96-0045). Moreover he is/was the scientist in charge of several bilateral research projects and grants, such as a German-Israelian project (GIF), a German-Swedish project (DAAD), German-Spanish project (DAAD) and a large German-Russian project (DFG). On the national level in Germany, he won in the year 2000 the *Leibniz-prize* by the German-research foundation (DFG), which includes a research grant of about 1.500.000 Euro. In addition he is the spokesman of the *DFG-Graduiertenkolleg* (graduate-school) in Elementary Particle Physics with many participants in Berlin and Dresden (total grant of about 2.000.000 Euro). He is also member of the running committee of the *DFG-priority programme* in string theory. Moreover he is/was conducting several substantial research grants by the DFG. Finally is a member of the steering committee of the 'Heisenberg-Landau'-project for the Joint-International-Institute in Dubna of the German ministry of education and research (BMBF).

He is a member of the *Berlin-Brandenburgischen Akademie der Wissenschaften*, he is external scientific member of the *Max-Planck-Institute for Gravitational Physics* in Golm, he is at the moment deputy director of the Institute of Physics at the Humboldt-university, and he is the editor in chief of the journal *Fortschritte der Physik.* He will be helped in his coordination by several very active scientists and by an efficient administrative staff.

B4.3. Management know-how and experience of network teams

Berlin The management know-how of Dieter Lüst, the scientist in charge of the Berlin group, was already described in the last section. The Berlin group is/was member in two EU networks, namely the RTN network *The Quantum structure of spacetime and the geometric nature of fundamental interactions* (HPRN-CT-2000-00131) and the TMR network *Quantum aspects of gauge theories, supersymmetry and unification* (ERBFMRXCT96-0045). He is currently coordinating the Greek-German scientific exchange programme IKYDA-2001-22, *Quantum fields and strings* between Patras, NTU of Athens and Berlin, Other members of the group have served in various committees, and the group was very active in organizing international workshops and conferences, such as the RTN-network meeting in 2000, the conference *Strings 1999* in Potsdam and the annual *Ahrenshoop meeting in particle physics*. The group is member of the German DFG-priority programme in string theory.

Potsdam Members of the groups have a long experience in collaborations with other European colleagues and institutes. All of us spent substantial time on positions in other European countries and still have close ties to these institutions. Therefore there are strong connections to most of the other teams in the present proposal. The scientific staff involved has educated a large number of PhD students that are now on positions in particle physics all over Europe. The institutes in Bonn and Golm continue to attract excellent students. Members of the present scientific staff are involved with key developments of particle physics and mathematical physics in Germany, including the set-up of international meetings both for students and more experienced researchers. These include: (i) a yearly spring conference at the center in Bad Honnef (this year the workshop took place March 9-13 and attracted 80 people), (ii) a yearly summer school for students in Saalfeld attended by around 40 students (many of the lecturers are participants of the current proposal) (iii) the international meeting of the Planck series attracts by now more than 100 people from all over the world. Planck99 was held in Bad Honnef (organized by the Bonn group) and Planck04 will return to Bad Honnef next year. The scientific staff of the node is actively involved in co-organizing numerous other meetings in Europe. The organization of these meetings, together with the individual contacts, will be a vital ingredient of networking as it always has been very instrumental for scientific collaborations and the discussion of administrative issues connected to the network.

Barcelona The Barcelona group is a member of the RTN network HPRN-CT-2000-00131, *The quantum structure of spacetime and the geometric nature of fundamental interactions*. It will organize the next Winter School of this network in January 2004 in Barcelona. The group of Barcelona collaborates in the organization of the Benasque Center for Science. The center organizes every two years an extended workshop in String Theory in the Pyrenees. Members of Barcelona and Valencia have functioned as EC experts. Some of them are involved in initiatives to improve the quality of research in Spain.

Madrid César Gómez, a member of the Madrid node, has been local coordinator of several Science projects, namely ERB-CHRX-CT92-0069 and ERB-FMRX-CT96-0012. Luis Ibáñez has been local coordinator of the TMR network project HPRN-CT-2000-00148. Members of the Madrid, Santiago and Oviedo groups have experience in successfully organizing international workshops (for instance the series of IFT-UAM-CSIC Christmas workshops on particle physics) and schools (for instance the Advanced School on Supersymmetry in the Theories of Fields, Strings and Branes, and the series of Fall Schools on Theoretical Physics).

Bures-sur-Yvette The IHES is a unique top-level scientific institution which hosts approximately 200 visiting scientists per year and has a top record in the management of scientific projects, including the EPDI, Geometric Analysis European network, a program on Genomics, and many others. Thibault Damour has been the chairman of the theory group of the space project STEP (Satellite Test of the Equivalence Principle) (European Space Agency projects M2 and M3), he was on the boards of Ecole Normale Superieure, Scientific Programs Committee of the National Center for Space Studies (France), Fundamental Physics Advisory Group (FPAG) of the European Space Agency. Nikita Nekrasov has co-organized several high level conferences (2 schools, 3 workshops, 3 conferences), a joint all-Paris string theory seminar; he was a scientific expert for several funding agencies (Austria, BSF (US/Israel), Chile, NATO, NSF (USA)). The team of Polytechnique has a long-standing tradition in networking and management of EU-related actions, since the first framework programmes became available: Science, Human Capital and Mobility, TMR, RTN, Individual Marie-Curie actions, etc. The following list is not exhaustive: SC1*-0394-C(EDB), CHRXCT92-0035, ERBCHBGCT930273, ERBCHBGCT930466, ERBCHBICT941413, ERBFMRXCT960090, FMRX-CT960045, FMRX-CT960090, ERBFMBICT982953, HPMF-CT-1999-00256, HPRN-CT-2000-00148, HPMF-CT-2000-00919, HPMF-CT-2001-01277. Other international or national cooperation programmes (INTAS, Programmes d'action integrée) were also run by this group. The permanent staff of Polytechnique have been involved in the (co)organisation of many scientific events such as international conferences (e.g. Susy 95), workshops (Euro-conferences, EU-network meetings etc.), schools (as in particular the Institut Henri Poincaré six-month training programme in 2000-2001), in Paris and elsewhere; the senior members of this team have various administrative responsibilities in boards, committees and graduate schools (EU, CNRS, Universities etc.).

Paris ENS The scientist in charge of the Paris node, Costas Kounnas, as well as the other members of the node have a long-standing tradition in EU-network management. Their expertise in this matter has been acknowledged since the late eighties, when they started running the very first European programmes in theoretical physics. Without being exhaustive, we mention the following: EU nrs ST2* 0360, SC1*-0394-C(EDB), SC1-0430-C (TT), SC1*-CT91-0650, SC1-CT92-0789, CHBICT93-0899, CHRXCT92-0035, CHBGCT93-0397, CHRX-CT94-0621, ERBFMBICT950213, ERBFMRXCT960012, FMRX-CT960045, FMRX-CT96-0090, HPRN-CT2000-00131, HPRNCT2000-00122, HPMF-CT2000-00508, HPMF-CT2000-00980, HPMF-CT-2001-01234, HPMF-CT-2002-01898, as well as numerous international, bilateral and national collaboration programmes. Many conferences, workshops, schools, in particular the IHP-Centre E. Borel (co-founded by B. Julia) 6-month training programme in Paris, 2000-2001, EU-network meetings and Euro-Conferences have been (co)organized by scientists of this node, in Paris, Cargèse, CERN, Corfu, Crete, Les Houches etc. Furthermore, senior scientists have miscellaneous administrative responsibilities as members of various national (CNRS, Universities and graduate school) and European boards and committees.

Copenhagen Nordita is a Marie Curie Training Site in particle physics under the contract

HPMT-CT-2000-00010 and Paolo Di Vecchia is the scientist coordinating this activity. He is also coordinating a Nordic project in string theory with the aim of organizing two Nordic meetings every year on the most recent developments for students and researchers of the five Nordic countries working in this field. He has also organized in the last 8 years three summer schools on field and string theories for students and young researchers of the Nordic countries with the participation also of students from other European countries and from America. All these schools were financially supported by the Nordic Agency NorFa. They were widely attended and very popular among the Nordic students. NBI and NORDITA have a long standing experience in the organization of workshops and are organizing a workshop in September 2003 on recent developments in string theory. Larus Thorlacius at the University of Iceland in Reykjavík currently represents Iceland on the NORDITA Board. He has been involved in organizing a number of workshops and schools including the Strings 1996 International Conference in Santa Barbara and a NATO Advanced Study Institute on Quantum Geometry in Iceland in 1999.

Dublin Samson Shatashvili, member of a Dublin node, very recently (June 2002) moved to Europe from USA where he was at Yale University since 1994. He successfully administered three major grants concurrently from NSF, DOE and the A. P. Sloane foundation. He was a member of the Yale inter-departmental Geometry/Symmetry/Physics group and was instrumental in organizing an extremely successful visitor programme and a postdoctoral programme at Yale. Many scientists who went through this program occupy leading positions in major research centers in the USA and Europe; some of them are members of others nodes in the current proposal. Also, in early 90's Samson was a member of an important APS committee that administered the grants for Eastern European countries after the Soviet Union disintegrated.

Frascati Sergio Ferrara, a member of the Frascati node, is currently coordinating an INTAS project INTAS-00-00254, *Branes, superconformal theories in diverse dimensions and partial breaking of supersymmetry*. In the past he acted as principal investigator of a DOE grant DE-FGO3-91ER40662, Task C at University of California Los Angeles, as well as a member of the scientific panel for selecting the NATO advanced study institutes (ASI). Stefano Bellucci, a member of the Frascati node, currently coordinates the NATO Collaborative Linkage Grant PST.CLG.979389, *Superconformal symmetry in mechanics, string theory and quantum field theory*, and is also the spokesperson for Frascati of the research grant Iniziativa Specifica MI12 on *String Theory and Quantum Field Theory* of the INFN theory national committee. Fabrizio Palumbo, a member of the Frascati node, has been scientist in charge of the third framework Science project *Gauge, Theories, applied supersymmetry and Quantum Gravity*, 1/9/92–31/8/96, the fourth framework TMR network project ERB-FMRX-CT96-0045, *Quantum aspects of gauge theories, supersymmetry and unification*, 1/9/1996–31/8/2000 and the current fifth framework RTN network HPRN-CT-2000-00131, *The quantum structure of spacetime and the geometric nature of fundamental interactions*. The group of Padova participated to the network projects SC1-CT92-0789 and ERB-FMRX-CT960045 and to the TMR network project HPRN-CT-200-00131 (local coordinator : Mario Tonin) as well as to two INTAS projects (INTAS 96-0308 and INTAS-100-00254) and to various Research Grant Projects of INFN called "Iniziative Specifiche". Dimitri Sorokin has organized two International Conferences in Kharkov in 1997 and 2000 and has been Scientific Supervisor of the NSC KIPT Programme on Atomic Science and Technology of Ukraine "Study of Fundamental Interactions of Elementary Particles" and of a Research Grant Project of the Ministry of Science and Technology of Ukraine.

Torino In the past few years, the groups of Torino and Alessandria have organized two European schools: one for the TMR network *Quantum aspects of gauge theories, supersymmetry and unification* in the winter of 2000, and one for the RTN network *The quantum structure of spacetime and the geometric nature of fundamental interactions* in the winter of 2003. The latter was organized also with the financial contribution of the Università di Milano. Both events have been highly appreciated and widely attended. Since the fall of 2001, Pietro Frè (scientist in charge of the Torino node) and Alberto Lerda (Alessandria) coordinate an Italian network in string theory, that includes researchers from nine different Italian Universities which has been selected and financed by the Italian Ministry of Education (MIUR) as a project of relevant national interest. Furthermore, Pietro Frè is a member of the board of ISASUT (International School of Advanced Study of the University of Turin) and of the DIASTP project (Dubna International Advanced School in Theoretical Physics); Stefano Sciuto served as Director of the Department of Theoretical Physics of the University of Torino from 1997 to 2002; Riccardo D'Auria was the Director of the Department of Physics of the Politecnico of Torino from 1996 to 2000; Alessandro D'Adda is currently the coordinator of the Theory Division of the Torino section of INFN, while Luciano Girardello (Milano-Bicocca) is the national principal investigator for the INFN research grant MI12, and Daniela Zanon (Milano) is the national principal investigator for the INFN research grant MI13.

Leuven Antoine Van Proeyen, member of the Belgian node, has successfully coordinated a third framework Science project *Gauge, Theories, applied supersymmetry and Quantum Gravity*, 1/9/92–31/8/96; a fourth framework TMR network project ERB-FMRX-CT96-0045, *Quantum aspects of gauge theories, supersymmetry and unification*, 1/9/1996–31/8/2000 and is currently coordinating a fifth framework RTN network HPRN-CT-2000-00131, *The quantum structure of spacetime and the geometric nature of fundamental interactions*. Antoine Van Proeyen and other members of the Belgian node intend to put their managerial experience fully at the disposal of the proposed project. Members of the node have functioned as EC, INTAS and BSF (Binational US/Israel Science Foundation) experts. Over the past decade, they have organized four international workshops and two schools, all which were widely attended and positively evaluated by the participants. Besides this, all three groups in the Belgian node are involved in various other initiatives. Most notably, they recently became core members of a Belgian *Network of Excellence*, mentioned above.

London Kellogg Stelle, Head of the Theoretical Physics Group at Imperial College London, has organized network conferences and schools on numerous occasions. These include in particular, the SCIENCE project conference in London in July, 1996 and the Centre Émile Borel semester "Supergravité, Supercordes et Théorie M," from September 2000 through January 2001, together with the associated RTN network Winter School. This research semester and school were attended by many young researchers from the whole European continent. He is in addition currently serving as External Examiner to the University of Edinburgh Department of Physics. The Imperial Theory Group runs one of the main MSc programs in Theoretical Physics in Europe. Members of the Group have organized numerous UK conferences and summer schools, notably the British Universities Summer School in Theoretical Elementary Particle Physics, held at Imperial in 1991 and at Queen Mary College in 2003. In addition, members of the Group have served on top-level grant assessment panels of the two main UK funding councils, PPARC and EPSRC. Imperial is a core member of the PPARC SPG Project in String Theory, linking it with Cambridge University, Kings College London and Queen Mary College, University of London. The Edinburgh group is also well experienced in the programme of scientific training. José Figueroa-O'Farriil is the main organizer of the North British Mathematical Physics Seminar, funded by the London Mathematical Society. This runs quarterly regional meetings together with Durham and York Universities, which are very well attended, especially by students, who are also encouraged to give talks.

Neuchatel The Neuchatel group has been a member of three consecutive european network programs (1992–2004), with Jean-Pierre Derendinger as scientist in charge. Both groups have regularly obtained grants through research proposals submitted to international evaluation. Long-term members of the two groups (Derendinger, Fröhlich, Felder) have accumulated a vast experience in the management of research groups, participation in various european networks, organizational activities (conferences, workshops, training programs) as well as academic responsibilities (faculty deans). Jurg Fröhlich is the leader of the Zentrum für theoretische Physik. Individually or in collaboration, the key staff of the node has developed over the years a very large network of scientific collaborations.

Patras Ioannis Bakas, member of the Greek node, has participated in the fifth framework RTN network HPRN-CT-2000-00131, *The quantum structure of space-time and the geometric nature of fundamental interactions*. He is currently coordinating the Greek-German scientific exchange programme IKYDA-2001-22, *Quantum fields and strings* between Patras, NTU of Athens and Berlin, as well as the NATO collaborative linkage grant PST.CLG.978785, *Algebraic and geometric aspects of conformal field theories and superstrings* between Patras, Rome, Paris and Sofia. He also organized a Euresco conference (2000) and two regional meetings (2002, 2003), which were very successful and well attended.

Sofia The group in Sofia is taking part in the ongoing 5th framework TMR Net *"EUCLID – Integrable models and applications: from strings to condensed matter"* as well as in the NATO-CLG *"Algebraic and Geometric Aspects of Conformal Field Theories and Superstrings"*. We are going to organize the 2004 *EUCLID*-network conference here in Sofia. The Sofia group has organized during the past three decades numerous international conferences, workshops and schools in QFT, mathematical physics, group theoretical methods including quantum groups (the latest one was the Fifth International Workshop *"Lie Theory and its Applications in Physics"*, Varna, June (2003)), *etc.* In the past few years the group of Craiova has been involved in the organization of three schools with international attendance: *1st Spring School on Quantum Field Theory, Supersymmetries and Superstrings*, 24-30 April 1998, Calimanesti, Romania, *2nd Spring School and Workshop on Quantum Field Theory and Hamiltonian Systems*, 2-7 May 2000, Calimanesti, Romania and *3rd Spring School and Workshop on Quantum Field Theory & Hamiltonian Systems*, 6-12 May 2002, Calimanesti, Romania. The main aim of these schools and workshops was to acquaint Romanian M.S. and Ph.D. students with some of the cutting-edge topics in Theoretical Physics.

Utrecht Bernard de Wit, scientist in charge of the Utrecht node, has extended management know-how and experience with network teams. The EU networks include 'Physical and mathematical aspects of the theory of fundamental interactions, string theory, field theory and integrable models' (ERBCHRX-CT92-0035), 'Quantum aspects of gauge theories, supersymmetry and unification' (ERBFMRX-CT96-0045), 'The quantum structure of spacetime' (HPRN-CT-2000-00131) and two INTAS networks. He was a director of two of the Trieste Spring Schools on supergravity in the eighties, Dutch scientific delegate of the CERN Council and the Committee of Council during the period 1994-2000, member and chairman of the NIKHEF governing board during 1978-1993, and member of the executive board of the central funding organization for physics in the Netherlands, FOM, since 1999. He was scientific director of the Utrecht Institute for Theoretical Physics. (1995-2000) and Director of Research of the Utrecht Faculty of Physics and Astronomy (2001-2003). The Utrecht node organized the RTN Winterschool associated with one of these networks in January 2002. On many occasions members of the node have organized international conferences and workshops.

B5 RELEVANCE TO THE OBJECTIVES OF THE ACTIVITY

B5.1. Benefits of network at European level

The scientific aspects of the proposal, as explained in section B1.1, and the training/transfer of knowledge aspects of the project, as outlined in section B2.2, make it clear that a concerted effort is needed in order to achieve the goals set forth. In fact, not a single country in Europe has all or even a significant part of the required knowhow to successfully complete the proposed project.

The EC networks, aided by the relatively small distances in Europe, considerably increase the mobility and thereby effectively create much larger, more productive and more attractive scientific pools.

B5.2. Benefits to the training and transfer of knowledge and research careers.

Research in the field of unified theories needs a lot of knowledge not only of the subjects directly related to field theory and string theory, but also needs intersectorial education, as e.g., on mathematical theories and cosmology. This education is not easy to organize at individual universities in Europe. This *fragmentation of education* can be tackled more efficiently at the European scale, and such an effort has actually started in previous 4th and 5th framework networks. The benefits to the researchers and to the research institutes have been a main reason for new nodes to ask to join this network.

Also *fragmentation of research* is overcome by the networks. The interchange of methods used to obtain similar goals is very fruitful. This happens often by the transfer of knowledge due to experienced researchers. E.g., different methods for constructing supergravity actions have now been combined and this knowledge is exchanged between the nodes due to postdocs that have been exchanged between nodes. The research in unified theories is based on many different techniques which have unforeseen connections. Transfer of knowledge is therefore a very useful tool to obtain progress, and the extension of the network will be important in this respect.

B5.3. Collaboration benefits.

Teams that by their size had restricted possibilities in the past have, by their inclusion into the previous networks grown to centers that can contribute significantly to progress in this field. The new network should provide the opportunities to fruitfully exploit their new expertise. Meanwhile new teams will be integrated into the collaborations, extending the possibilities for the project, and the inclusion of new countries will provide new experiences for young researchers.

The established collaborations will remain an asset for teams in the future. The previous networks were a first step for the researchers in this field to come together in a coordinated effort to maintain a strong position worldwide. The collaboration is more necessary now than ever due to increased possibilities for exchange, which are used also in other continents. The new network is the necessary continuation in order that the obtained collaboration structure does not become lost. The extension to new countries and universities will allow the establishment of a truly European common force for fundamental research.

B5.4. Special interests for the research area at EC level.

Theoretical elementary particle physics is a highly internationalized and highly competitive field. While pressure from the United States has always been very high, Europe has managed to play a central role in the development of both elementary particle physics and cosmology. Indeed, many of the seminal ideas underlying string theory and supergravity originated in Europe. The presently proposed RTN will further enhance Europe's position with respect to the United States. This is not without practical importance. Indeed, while the field itself consists of pure theoretical research, it produces novel ideas and insights which trigger the development and construction of important experimental facilities. This in turn has not only major industrial and financial implications but it leads to the development of novel technologies, which find important applications in domains unconnected to particle physics (e.g. medical imaging, IT applications such as the GRID, novel electronics, ...). Sometimes, these developments are unforeseen but turn out to have a revolutionary impact on society (e.g. the World Wide Web, which was for Particle Physics at CERN).

The proposed project will significantly increase the overall capacity to train / achieve transfer of knowledge in this particular field in Europe. The EC networks in which we were or are currently involved have effectively changed the scientific career situation in our field in Europe. Indeed, while till less than a decade ago, a majority of the young, very capable researchers did pursue a career in the United States, this situation has changed now. The reasons for this are manifold. Because the US groups are typically much larger than the European ones, they cover a larger portion of the field and as a consequence they function more effectively both at the level of scientific research as at the level of training. As a result, the US groups were much more attractive to ambitious young European scientists.

The EC networks, aided by the relatively small distances in Europe, considerably increase the mobility thereby effectively creating much larger, more productive and more attractive scientific pools.

Besides improving mobility, a network creates a substantial number of research positions for young scientists. In particular, it provides ample post-doctoral career opportunities, something which is not widely available at national level. Through the organization of schools, workshops and working groups, training opportunities are being created of a magnitude and quality that was not available in Europe till some time ago.

While this demonstrates that, thanks to the European Research and Training Networks, the scientific climate for our field of research in Europe has certainly progressed, it should be clear that in order to maintain and even to improve the situation, a continued investment is required.

Finally, the commissioning of the Large Hadron Collider (LHC) at CERN in 2007, the potential future projects at DESY in Hamburg, the gravitational wave research facility Virgo, various scheduled ESA missions, such as Planck, ... all together adding up to a major European scientific effort and representing a multi-billion euro investment, are clearly priorities on our continent. The merit of these projects is not only scientific; they also have a very large impact on industry and technological progress in Europe. It is obvious that a venture on such a scale requires a very sizable, supporting scientific framework, both in terms of manpower and scientific assets.

The scientific and training goals proposed in the present project will fill this necessity and will provide ample and essential support to the aforementioned projects. Indeed, Europe is faced with a declining number of young people pursuing a career in (applied) sciences. If in addition the best of these young scientists are tempted to establish their career in the United States, then we are heading towards an untenable situation. The network will provide Europe with a significant pool of attractive career openings together with abundant training opportunities of high quality. In addition, the scientific goals of this project are closely related to the scientific missions described before.

B6 ADDED VALUE TO THE COMMUNITY

B6.1. Contribution to the objectives of ERA and community policies.

We address the objectives of the European Research Area as they were formulated in the *Communication from the commission to the council, the European Parliament, the economic and social committee and the committee of the regions* on January 18, 2000. From the previous sections, it should be clear that many of the stated objectives are being met in the present proposal. We will mention some of the main ones (the numbers refer to the section in the above-mentioned document):

- *1.1 Networking of centers of excellence in Europe and creation of virtual centers.* The proposed network brings together a sizable fraction of Europe's leading research centers in our field. Several mechanisms (schools, workshops, lecture series, working groups, staff and student exchanges, ...) are foreseen in order to ensure a smooth collaboration between these groups and to ensure adequate training. Dedicated webpages devoted to scientific discussions, electronically advertising open positions, fully automated application procedures, making recorded seminars and lecture series (or at least copies of overheads) available online, the use of electronic archives (such as hep-th) for rapid communication of scientific results, ... all contribute to the creation of a virtual environment which greatly enhances the networking and scientific capabilities of the groups involved.

- *5.1 Greater mobility of researchers in Europe.* The most fruitful scientific methodology in theoretical physics is the face-to-face black board discussion. In order to have successful collaborations between different groups, mobility is of paramount importance. Many of the groups involved in this proposal have a long, proven track record of thriving scientific collaborations. Watching the evolution of the three EC networks that we have been involved in until now (covering a period from 1992 through the present), one notices an ever increasing number of international collaborations which goes hand in hand with a continuously increasing mobility (e.g. this manifests itself in the form of an increasing number of working visits and exchanges of research staff and students). With the introduction of the novel aspect of workgroups (as explained under B1.4), we hope to even further improve the mobility and the scientific collaborations.

- *5.2 Introduction of a European dimension to scientific careers.* The larger part of the requested funding will be used to finance positions for early-stage and experienced researchers. Experience with the presently running network shows that there is no recruitment problem at all. Indeed, we do receive many times more applications than there are positions available, thereby greatly improving the chances of hiring truly talented young scientists. The RTN provides us with the possibility to follow a hiring scheme similar to the one used by US universities and institutions and which allows us to compete with them. Indeed, after advertising, candidates apply for positions and selections are made in January. Contracts traditionally start beginning in September or October. While national policies generally do not allow for such flexibility (which in the past was reflected by the fact that most talented young Europeans continued their career in the US), the RTN positions allow in many cases for "local matching". In this way, we have managed in the currently running network to effectively more than double the number of man-months. In the proposed network, we intend to further elaborate this scheme so that, starting from the RTN funded man-months, combined with the use of local funding, we arrive at a significant increase in the number of man-months available for early-stage and young researchers in our field.

- *5.4 Giving the young a taste for research and careers in science.* While this project is in the first instance a research and training proposal, we have noticed that the scientific topics addressed in this proposal appeal to a large audience which include numerous young people. This calls for a serious commitment to outreach which in turn might have a positive influence on the inclination of young people to pursue a scientific career. We intend to put serious effort into establishing an extensive set of webpages introducing non-specialists to our discipline. A first step in this direction has been set by Jan Troost (presently at MIT) who was trained at the Belgian node and who will soon be joining the Paris ENS node of our network. His pages, hosted at the Belgian node at `http://tena4.vub.ac.be/beyondstringtheory/`, which already enjoy a large popularity, will serve as a starting point for this effort.

- *6.2 Integration of the scientific communities of western and eastern Europe.* See below under B.6.2.

- *6.3 Making Europe attractive to researchers from the rest of the world.* See below under B6.4.

Concluding, the present RTN proposal makes a very significant effort to do away with the compartmentalization of national research policies in our particular subfield of physics following closely the policy outlined for a European Research Area. Past and current networks demonstrated that the RTN scheme is indeed a very successful way to achieve this in a smooth and natural way.

B6.2. Integration of candidate countries

The coordinated efforts for research and for education of young researchers that were developed in previous networks will now also be available for Eastern European countries. We include a Bulgarian node, which will obviously enable them to participate in front-end research and contribute to the education of their researchers in advanced and timely subjects. Moreover we will allow young researchers of the other candidate countries to participate free of inscription fee to all our network schools and workshops.

B6.3. Gender balance

The number of enough women researchers in theoretical high energy physics is very small. Though we tried in the previous years to select women as network young researchers, we could only do so in a few cases because we just did not have enough women candidates. We hope to improve on this situation due to the inclusion of Early Stage Researchers in the new network. By acting at this earlier stage in research careers, we hope to be able to stimulate women to be involved in network activities. In the long term, the fact that women are encouraged at this early stage will be helpful also for redressing the balance at later stages in their careers. The secretary for recruitment of young researchers will have to make sure, as a matter of priority, that women should be encouraged to enter the network activities in this way.

B6.4. Attractiveness and competitiveness of Europe for researchers

Past and current networks have greatly enhanced the scientific quality and as a consequence the attractiveness of the groups involved. Because of this we have noticed an ever increasing number of job applications coming from young, very bright scientists from South America, Japan, India, Korea, ... and even from the United States. Under the previous EC rules, these people were not eligible. However the present rules radically alters the situation and will enable us to hire some of these young scientists. This will be a way (as it already happens since a long time in the United States) to cope with the decreasing number of physics students in Europe.

Competitiveness will be increased due to the buildup of European virtual centers as described above in B6.1. under item 1.1, which addresses the problem of competitiveness in comparison to U.S. groups as described in section B5.4.

All this will lead to a *European structure* where much of the expertise available between all the European countries is used in a co-ordinated way to obtain maximal performance of research, and to be attractive to young researchers.

B6.5. Coordination or synergy with national programs and longer-term effects

The network has a tradition of combining EC funds with national funds to obtain nearly a doubling of the postdoc positions. This has happened in the past and will be extended in the upcoming project. In particular, we mention the following national programs that are for a large part due to the EC network.

In Germany the DFG (Deutschen Forschungsgemeinschaft) has a 'Schwerpunktprogramm' with as subject "Stringtheorie im Kontext von Teilchenphysik, Quantenfeldtheorie, Quantengravitation, Kosmologie und Mathematik" that contains several groups of our network (even including Leuven in Belgium as international partner). The Max-Planck-Institute in Potsdam and the Humboldt-University in Berlin are members of a "Max-Planck-International Research School" on string theory and related topics which provides positions and training for PhD-students in this field.

In Belgium the teams in the network are part of an 'Inter-University Attraction Pole', on "Fundamental Interactions: at the Boundary of Theory, Phenomenology and Experiment", which allows a smooth interaction with this network, especially to produce suitable postdoc positions.

The Dublin node is currently supported by Basic Research grant from Science Foundation Ireland (this grant until last year was administered by Enterprise Ireland). Dublin node will be getting also a strong support in a form of visitor program from recently founded Hamilton Mathematics Insitute (HMI) at Trinity College Dublin where prof. Shatashvili is a Director.

In Italy, several groups of our network are supported by the Istituto Nazionale di Fisica Nucleare through "Iniziative Specifiche" on topics related to the program of the EC network. All groups of our network are also part of an Italian collaboration on "Teoria dei campi, superstringhe e gravità" (project number 2001-1025492) that has been selected and financed by the Italian Ministry of Education as a project of relevant national interest. This Italian network will allow a fruitful collaboration and integration with the proposed European network, in particular in providing extra funds for post-doc positions.

In Denmark early stage researchers for 24 months have the possibility to obtain an additional 12 months matching funds from FUR (Forsknings Uddannelse Raad), thus facilitating a full 3 year PhD grant. It may also be possible to extend postdoctoral positions with the aid of the programs of SNF (Statens Naturvidenskabelige Forskningsraad) or directly by Nordita.

In the Netherlands the members of the Dutch node participate to the national FOM programmes *Fundamental Interactions* and *String Theory and Quantum Gravity*. Furthermore they have at several occasions obtained grants for both early stage and experienced researchers via a special programme (the so-called "projectruimte") of the National Research Foundation

(FOM). It is expected that the upcoming project will benefit from these interactions.

In Paris the *Centre National de la Recherche Scientifique* (CNRS), the *Commissariat à l'Energie Atomique* (CEA) and the *Ministère délégué à la Recherche et aux Nouvelles Technologies* contribute to the visitor budget of the laboratories. This budget is used for doubling the duration of the EU post-doc positions. The majority of the staff members have either CNRS or CEA positions.

In the UK, there is high degree of synergy between European research and training programmes and national research and training programmes. Both relevant UK research councils PPARC and EPSRC support a wide range of scientific research, from postdoctoral fellowships to special projects grants to support research in particular focus areas, for example in string theory. In addition, there are numerous conferences at major universities around the country supported by a range of public and private funding organizations. It has been our practice to combine as smoothly as possible European support with local funding to enrich the London research climate.

In Spain there exists a National research program in high energy physics (Plan Nacional de Altas Energias), depending on the ANEP (National Science Agency), and a programme (Programa Ramon y Cajal), depending on the Ministerio de Ciencia y Tecnologia, which is a program specifically addressed to the creation of 5-year postdoctoral positions. In the autonomous region of Catalonia there is a Catalan research institution, ICREA. ICREA offers to leading researches in all fields of knowledge long term contracts at senior and junior level. Among the priority lines of ICREA there is String Theory.

Members of the Greek node are/were holding two reasearch grants for PhD students (duration of 36 months each) and one research grant for postdoctoral appointment (duration of 24 months) awarded by the University of Patras under the local programme "C. Caratheodory" aiming at the advancement of basic research. A similar programme is now becoming available at NTU in Athens.

In Switzerland there ae research grants obtained from the Swiss National Science Foundation.

The participants from the Sofia node are involved in a series of current research projects financially supported by the Bulgarian National Science Foundation, which are closely related with the research areas of the present RTN project. The topics of these national projects are as follows: (a) "Two-dimensional integrable models - application of quantum group and conformal invariance"; (b) "Lie Theory and Its Applications in Physics"; (c) "Infinite-dimensional, generalized and q-deformed symmetries, and their applications in quantum physics".

The Craiova team is involved in several research projects, supported by the Romanian National Council for Academic Scientific Research and the Romanian Minstry of Education, Training and Youth, which are related to the research areas of the present project, like: "Field theories with nonlinear gauge algebras", "Self-interactions and the Lagrangian BRST cohomology" and "Couplings among nonlinear theories and some collections of one-, two- and three-forms".

This shows that the efforts are part of a longer term evolution of coordinating research, already present in FP5, which can now be further developed in FP6.

B7 INDICATIVE FINANCIAL INFORMATION

In order to provide indicative financial information on the network project (excluding expenses related to the recruitment of early-stage and experienced researchers), as shown in the table below, we first give an estimate of the budget associated with the appointment of the early-stage and experienced researchers. The calculation assumes giving regular employment contracts to all experienced researchers and giving stipends to the early-stage researchers, except in the Bures-sur-Yvette, Paris, Leuven and Utrecht nodes. Moreover, a number of participants are in the process of negotiating with administrations about the possibility of providing fixed-amount stipends also to experienced researchers. In this case, the number of man-months will increase accordingly. According to the rules, the average two-year costs of a researcher for every participating country are obtained, by adding (a) the basic living allowance of 89.000 Euro for an experienced researcher with employment contract, resp. 58.000 Euro (29.000 Euro) for an early-stage researcher with employment contract (stipend), (b) the travel allowance of 2.000 Euro, (c) the mobility allowance for an unmarried researcher of 14.400 Euro, resp. 21.600 Euro for a married researcher, (d) the career exploration allowance of 2.000 Euro and (e) the provision for networking costs of 9.600 Euro. Items (a) and (c) are subject to correction by the country-dependent coefficient. Then, taking into account the amounts of months/years presented in section B2.2 one finds for (a) – (e) a total of 3.181.320 Euro for researchers.

Next we take that the personnel costs described above make 65% of the total budget, which then approximately corresponds to 4.894.338 Euro. Subtracting from this a flat rate of 10% for the overhead, and 60.000 Euro for management costs, one is approximately left with an amount of 1.163.584 Euro available for expenses for network activities, which are shown in the following table (the coordinating team has an extra of 97.984 Euro reserved for common activities, such as network conferences and schools). (Column (A) refers to networking costs of researchers not appointed by the network, such as collaborations and for participation in network meetings, column (B) is foreseen for the expenses for the organisation and implementation of the project such as the exchange of information, materials, maintenance of a website, however not requested by our network, and column (C) is devoted to management activities, where (C) will be only requested for the coordinating team; finally column (D) is foreseen for durable equipment such as computers, which however will not be necessary for our network):

Indicative financial information on the network project (excluding expenses related to the recruitment of early-stage and experienced researchers				
Network Team No.	Contribution to the research/ training/ transfer of knowledge expenses (Euro)		Management activities (including audit certification) (Euro)	Other types of expenses/specific conditions (Euro)
	(A)	(B)	(C)	(D)
1. Berlin	142.384		60.000	
2. Potsdam	88.800			
3. Barcelona	44.400			
4. Madrid	44.400			
5. Bures	59.200			
6. Paris	74.000			
7. Copenhagen	59.200			
8. Dublin	29.600			
9. Frascati	118.400			
10. Torino	133.200			
11. Leuven	103.600			
12. London	59.200			
13. Neuchâtel	44.400			
14. Patras	44.400			
15. Sofia	44.400			
16. Utrecht	74.000			
Totals	1.163.584		60.000	

B8 PREVIOUS PROPOSALS AND CONTRACTS

Many of the groups participating in the present proposal were involved in the following networks,

Third framework: Science project SC*1-CT92-0789 *Gauge, Theories, applied supersymmetry and Quantum Gravity*, 1/9/92–31/8/96.

Fourth framework: TMR network project ERB-FMRX-CT96-0045 *Quantum aspects of gauge theories, supersymmetry and unification* (Gauge theory-susy-unification), 1/9/1996–31/8/2000.

Fifth framework: RTN network HPRN-CT-2000-00131: *The quantum structure of spacetime and the geometric nature of fundamental interactions* (Quantum spacetime), 1/10/2000–31/9/ 2004.

These networks have been very successful. Indeed both the scientific and training aspects of the fourth framework TMR were successfully concluded as 159 joint publications testify. The currently running fifth framework RTN produced up to the moment of the mid-term report (which covered the period October 1, 2002 – June 15 2002) 112 joint publications. The network runs smoothly and the research objectives will be reached. To illustrate this, we included the mid-term review in an annex to this proposal.

However, we would like to stress that the present proposal should *not* be viewed as a mere continuation of the fifth framework RTN. Indeed, while the subject is part of the same field of research, it should be abundantly clear from the previous sections that the scientific goals have been radically altered and updated. On top of that, the composition of the presently proposed network has been adjusted compared to the running network HPRN-CT-2000-00131. Indeed, the Heraklion and Genova groups do not participate any more while additional groups from Bulgaria, Greece, Iceland, Ireland, Spain, Switzerland and the U.K. have been added. This serves a twofold purpose. It is clear that the geographic distribution of the proposed network has improved a lot compared to the previous ones. On top of that, it is essential for the successful completion of the research programme that new expertise and technological skills are obtained by the input of additional nodes.

B9 OTHER ISSUES

The present project is clearly concerned with fundamental scientific research aimed at a better understanding of our universe. As a consequence it is mainly driven by human curiosity and it does not imply any ethical or safety issues. However, the subjects treated in this project (elementary particle physics, cosmology, ...) do appeal to a wider audience. As a consequence, we envisage a serious commitment to outreach. This will be achieved by means of a dedicated web page. The starting point for this will be the webpages, hosted at the Brussels subnode, found at
`http://tena4.vub.ac.be/beyondstringtheory/`,
whose author Jan Troost (trained at Brussels and Leuven, presently at MIT) will be, from October 2003 on, associated to one of the participating nodes (ENS, Paris).

Does the research presented in this proposal raise sensitive ethical questions related to:	**YES**	**NO**
Human beings		NO
Human biological samples		NO
Personal data (whether identified by name or not)		NO
Genetic information		NO
Animals		NO

We confirm that the research presented in this proposal does not involve:

- Research activity aimed at human cloning for reproductive purposes;
- Research activity intended to modify the genetic heritage of human beings which could make such changes heritable ;
- Research activity intended to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer;
- Research involving the use of human embryos or embryonic stem cells with the exception of banked or isolated human embryonic stem cells in culture.

ENDPAGE

HUMAN RESOURCES AND MOBILITY (HRM)
ACTIVITY

MARIE CURIE ACTIONS
Research Training Networks (RTNs)

PART B

“ForcesUniverse”