European Cooperation in the field of Scientific and Technical Research - COST -

Brussels, 21 November 2012

MP1210

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action : The String Theory Universe

Delegations will find attached the Memorandum of Understanding for COST Action as approved by the COST Committee of Senior Officials (CSO) at its 186th meeting on 20 - 21 November 2012.

MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action designated as

COST Action
THE STRING THEORY UNIVERSE

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4154/11 “Rules and Procedures for Implementing COST Actions”, or in any new document amending or replacing it, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to exploit complementary expertise of different research groups in Europe to enhance the understanding of String Theory and its applications to Particle Physics, Condensed Matter, Cosmology and Quantum Gravity.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 60 million in 2012 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter V of the document referred to in Point 1 above.

A. ABSTRACT AND KEYWORDS

Although String Theory has been around for more than forty years, it has never been so important for physical reality as it is now, due to its novel outstanding applications to different areas of Physics and Mathematics.
While the Large Hadron Collider (LHC) narrows down the experimental limits on supersymmetric particles and satellite missions such as The Wilkinson Microwave Anisotropy Probe (WMAP) and Planck probe the very early Universe, this Action aims at creating a strong European Network focused on fundamental, forefront research exploring the role played by String Theory in Particle Physics, Cosmology and Condensed Matter Physics.
The large majority of European world experts in String Theory will be involved in this Action. This will ensure a top quality research output, achieved through an intense exchange of expertise, intra-European collaboration and co-organization of scientific activities.
The Action will ensure fair gender representation and simultaneously adopt specific measures for promoting the involvement of women scientists at all levels. Moreover, it will foster the active participation of junior excellent scientists.
The outcome of the Action is expected to have a positive impact on both science and society at a European level, in line with the strategic priorities of COST.

A.2 Keywords: String Theory, Gauge/Gravity Correspondence, String Phenomenology, String Cosmology, Black Holes

B. BACKGROUND

B.1 General background

In recent years, String Theory (ST), known as the most consistent theory unifying Quantum Gravity and the Standard Model (SM) of particle interactions, has grown as a rich mathematical structure that has allowed outstanding applications to very different areas of Physics and Mathematics.
The most striking achievement of ST in the last decade has been a new way of modelling strongly interacting systems. This picture-changing paradigm is encoded in the so-called AdS/CFT (Anti de Sitter/Conformal Field Theory) or gauge/gravity correspondence. It states that many complex quantum systems in strong coupling regimes, where traditional methods of investigation only partially succeed, can be described by a weakly coupled ST or, equivalently, by a higher-dimensional classical theory of Supergravity. This map discloses new important properties of field

theories (integrability, dualities) and leads to crucial new insight in strongly coupled systems, like the quark-gluon plasma (tested at Relativistic Heavy Ion Collider (RHIC) and LHC accelerators) and critical phenomena in Condensed Matter systems (superfluids, superconductors and cold atoms). This provides an exciting new way to connect ST to observation.

ST has the potential to describe Particle Physics beyond the SM. As ST involves extra dimensions, viable phenomenological scenarios are achieved via compactification schemes to four dimensions. This approach has allowed preliminary contacts with Particle Physics phenomenology, like TeV scale supersymmetric (SUSY) extensions of the SM and their implications for potential discoveries of beyond the SM phenomena at the LHC experiments. ST also provides a theoretical framework for alternative scenarios for new physics, like SUSY breaking at other scales or the realization of dark matter particles.

Building upon the wide range of cosmological observations, a comprehensive but phenomenological description of the history of the Universe has been developed. ST is the natural framework for a consistent theory of Quantum Gravity, and as such it can answer fundamental theoretical questions concerning the origin of the Universe, its expansion and the ultimate nature of space-time and its singularities. ST has delivered the most convincing microscopic description of Black Holes that accounts for their entropy. The AdS/CFT correspondence has far reaching consequences also in this direction, where important questions such as the information paradox are addressed.

High precision experiments in Particle Physics and Cosmology in the next few years will allow comparision of theoretical predictions coming from ST at an unprecedented level of accuracy. While SUSY and extra dimensions will be tested at the LHC, measurements by current satellite missions (WMAP and Planck) will probe the very early Universe where Quantum Gravity effects are crucial.

The main objective of this Action is to create a strong, interconnected network of experts working on Gauge/Gravity duality, String Phenomenology and Cosmology and Quantum Gravity. Important progress will be achieved through an intense exchange of expertise among the different teams, naturally reinforcing European leadership in theoretical high-energy physics.

The Action will promote the emergence of young talents who will find opportunities and strategic support for their future carriers. It will bring into action general EU and specific COST policies in gender issues to redress the significant gender imbalance currently present in this field of research. This Action focuses on networking and cooperation, and foresees scientific progress and outcome for society; thus COST offers the best framework.

B.2 Current state of knowledge

Most foundational and applied research in ST currently revolves around three major topics:
Gauge/Gravity duality. Since the original formulation of the AdS/CFT correspondence, research in this area has been focused on two main directions. On one side, impressive progress has been made in understanding the foundations of the correspondence and in unveiling its many hidden symmetries. One of the main outcomes of the AdS/CFT correspondence is the highly unexpected link between SUSY field theory and two-dimensional integrable systems. The best understood example is by now the maximally SUSY gauge theory in four dimensions (N=4 super Yang-Mills) and its string dual, where integrability can be used to solve the full planar spectrum and compute many physical observables like scattering amplitudes and correlation functions. This paves the way to determine the first exact solution of a four-dimensional interacting gauge theory. Theories in different dimensions and with a different amount of SUSY are also under investigation, with the aim of disclosing general properties that, if model independent, could point towards the deep nature of the AdS/CFT correspondence.
On the other side, the AdS/CFT correspondence has been extended in many different ways to less SUSY and non-scaling invariant field theories, more suitable for applications to real physical systems like low-energy Quantum Chromodynamics (QCD), heavy ion physics, Condensed Matter systems and quantum criticality. This more general form of the correspondence is often referred to as gauge/gravity (or holographic) duality. Significant results for transport phenomena and phase transitions have already been obtained, and applied successfully to the quark-gluon plasma, now under study at RHIC and LHC. Gauge/gravity duality is naturally suited for addressing the notoriously difficult problems of non-equilibrium systems and thermalization (these are among the five Grand Challenges of the US Department of Energy), since it naturally incorporates time dependence.
String Phenomenology. ST comes with SUSY and extra dimensions. The main strategy to derive the SM of Particle Physics from ST is to embed it in a larger theory where SUSY is broken at the TeV scale (this is where new physics is expected to show up at LHC, for instance). Such a theory comes from compactifying on a particular internal space, a so-called Calabi Yau (CY) manifold. There are by now, two types of phenomenological models, which give rise to SM-like theories: heterotic string models, involving magnetic field fluxes on the CY geometry, and Type II string models, based on D-branes (extended topological solitons). These two approaches intertwine via string dualities, motivating the search for non-perturbative frameworks encompassing them. One avenue is the inclusion of non-perturbative effects (D-brane instantons) in D-brane models,

which can generate interesting new charged matter interactions. Another possibility is F-theory, where brane models with known heterotic duals allow for structures of Grand Unified Theories (GUTs).

ST extensions of the SM require mechanisms to break SUSY. If sourced at high energies (gravity mediation), they are deeply connected with moduli stabilization, i.e. the need to generate masses for many ubiquitous neutral scalars, for example by the addition of fluxes or anti-D-branes. Partial quantitative understanding of their effects has allowed a (still incomplete) contact with Higgs and SUSY phenomenology at the LHC. A similar effort has been carried out in other scenarios (gauge mediation), where the AdS/CFT correspondence is employed to study strongly interacting sectors. In a complementary approach, ST can provide a theoretical framework for SUSY breaking at high-energy scales, and for alternative scenarios for new physics, like dark photons arising from new massive vector bosons, or dark matter particles realized as axions associated to the extra dimensions.

Cosmology and Quantum Gravity. In spite of serious efforts over more than a decade, it turns out to be very difficult to implement inflation and the present accelerating expansion of the Universe in ST. The standard way to accomplish this begins with the search for string compactifications that lead to (metastable) four-dimensional accelerating universes of the type of de Sitter space-time. This typically involves understanding moduli stabilization mechanisms. By now this has led to a few (not fully satisfactory) proposals for how this could be achieved. The moduli fields and their scalar potentials need to be controlled rather precisely in order to read off the observational consequences of a model. One should take into account also constraints from limits on SUSY breaking and dark matter candidates. A signature of some ST inflationary models is the presence of extended objects (cosmic strings), which, if detected, could provide an exciting observational window onto ST itself.

Research in Quantum Gravity has been powerfully driven by the theoretical study of Black Holes. ST has led to impressive progress in understanding the microscopic physics of SUSY extremal Black Holes. Despite all these advances, a full understanding of more realistic Black Holes and of the newly found solutions with other horizon geometries and topologies (black rings, blackfolds) has not yet been achieved. A more systematic investigation of all these solutions, both at classical and quantum level, will result in qualitative advances in our comprehension of Quantum Gravity and the emergence of space-time.

These results have been accomplished by different groups based in world-leading Institutions in Europe and in the United States. In the US, the productivity in this field of research has recently increased due to the mobility of researchers, and active networking via seminars and visits throughout the country. The present Action will have a similar effect in Europe, enhancing our leadership in this area.

B.3 Reasons for the Action

"The String Theory Universe" Action will be innovative in unifying research activities in Gauge/Gravity duality, String Phenomenology and Cosmology and Quantum Gravity under a common platform. Coordination inside and across the three areas will counteract fragmentation of research efforts in ST and reinforce European leadership, especially on interdisciplinary aspects of ST and its innovative applications, to which European scientists have made leading contributions. Most of the applicants have participated in past EU research Networks on ST, which have provided longstanding research links and collaborations. These collaborations are nowadays informal and receive no network funding. This COST Action will support the strong links already existing and promote new collaborations. This will open the way to optimal integration of all ST-research efforts underway.

The participation of scientists from Non-COST countries will be crucial in opening the European Research Area to cooperation with the South Cone and North America.

High precision experiments in Particle Physics, Cosmology and Condensed Matter in the next few years will allow testing theoretical predictions coming from ST at an unprecedented level of accuracy. Progress in this program will be crucial for bridging the gap between ST and experiment. Launching the present COST Action now is very timely, given the impressive amount of new experimental data that will be soon available from the LHC and RHIC accelerators and from current satellite missions (WMAP and Planck).

The Action will promote contacts with specialists in applied Particle Physics, Condensed Matter and Cosmology, who will further new perspectives for the already existing applications of ST to these fields.

Early stage researchers (ESRs) will find a platform that will enable them to get in contact with leading groups in String Theory.

This Action will actively address the issue of gender imbalance in a field of research in which the presence of women is estimated to be well under 10%. It will serve as a platform in which to bring into action specific policies in gender issues, aimed at redressing the current asymmetric situation.

There is no other networking project at the moment that

1) Links research on the main scientific areas in String Theory.

2) Fosters cooperation with broader areas in Physics to which String Theory has provided crucial

applications.
3) Promotes actions addressing gender imbalance in high-energy theoretical physics.

B.4 Complementarity with other research programmes

Being cross-disciplinary, this Action is complementary to ongoing EU projects which are funding the study of individual aspects contained in this Action. These are: the FP7 ITN network UNILHC, which funds research activities in String Phenomenology, the ESF network HoloGrav, which brings together nationally funded research on applications of the gauge/gravity correspondence, and the COST Action MP0905, built upon the integrated experimental, technical and theoretical research on Black Holes.
Some of the scientists participating in this Action are also naturally involved in these networks. Strong links with these projects and collaboration in the organization of joint workshops and seminars will be fostered. This will ensure that knowledge from this Action will be transferred to and from these networks.

C. OBJECTIVES AND BENEFITS

C.1 Aim

The main objective of the Action is to exploit complementary expertise of different research groups in Europe to enhance the understanding of String Theory and its applications to Particle Physics, Condensed Matter, Cosmology and Quantum Gravity.

C.2 Objectives

The main expected deliverables of this Action are:

- Coordinate the research activities of different groups working on String Theory, in order to foster and consolidate collaborations.

- Encourage transfer of knowledge and exchange of conceptual and technical tools among groups working in different areas of String Theory.

- Establish communication with experienced researchers in broader areas of Physics and Mathematics to foster new potential applications of String Theory.
- Promote and support the emergence of young talent.
- Act as a platform for preparing joint training of young researchers.
- Contribute to the implementation of specific university internationalization programs currently running in some of the Action's countries.
- Promote actions to counteract the considerable gender imbalance in theoretical high-energy physics.
- Intensify outreach activities in schools to motivate students to undertake a scientific carrier.
- Counteract cultural barriers that prevent women from pursuing a scientific carrier.
- Contribute to an adequate development of the scientific culture in Europe.

C.3 How networking within the Action will yield the objectives?

The objectives of the Action will be achieved through:

- Regular Working Group meetings, Workshops, Training Schools and joint seminars.
- Exchanges of staff and young researchers between the participating groups, via Short-Term Scientific Missions (STSMs).
- Development of cross-disciplinary research activities.
- Joint cross-disciplinary training programme for ESRs and young researchers.
- Expansion of the initial COST Action by integrating other Non-COST countries.
- Coordination of the selection procedure for postdoctoral positions in ST across Europe.

- Specific gender-related activities devoted to increase visibility of women scientists both within and beyond the Action and to ensure equal opportunities.
- Specific outreach activities for school pupils and young students.
- Special outreach activities for girls and young women.
- Dissemination of the results among the scientific community.
- Dissemination of the work to wider public and political audiences.

C.4 Potential impact of the Action

Scientific benefits of the Action will be:

- Overcoming the fragmentation of research efforts in theoretical high-energy physics in Europe, thus reinforcing European leadership in this area.
- Intense exchange of expertise, scientific tools, scientific achievements, human resources and experience.
- New insights into deep central questions in theoretical physics with important implications on high-energy Physics, Cosmology, Condensed Matter and Black Holes. Progress in this program will reduce the gap between ST and experiments.
- Reinforcement and development of long-term collaborations.
- Improvement in the quality of research and innovation coming from an increasing female participation.

Specific benefits for ESRs will be:

- Cross-disciplinary international high-level education.
- Exposure to updated overviews on the most important results in the different subjects.

- More visibility within the scientific community.
- A coordinated distribution of postdoctoral opportunities within the Action.

Benefits for women scientists will be:

- Identification of specific actions to redress gender imbalance.
- Equal opportunities within the Action.
- More visibility within the scientific community.

Specific benefits for society will be:

- The formation of well-trained, competitive European researchers capable of taking a leading role in their future employment in international environments.
- An increasing attraction of the general public towards the fascinating world of elementary particles and the origin of our Universe.
- A reinforcement of the scientific education of pupils and high-school students.
- A key contribution to university internationalization programs currently running in some of the Action parties.
- A crucial support to policy-makers in finding a EU-wide consensus on gender policies.

C.5 Target groups/end users

The main target group addressed in this Action are scientists and young researchers at European Institutions (Universities and Research Centers), over 200 of which have been contacted and have indicated their interest in the Action. Beyond that, general knowledge will be shared globally with the international scientific community.
Special attention will be paid to the sub-group of female researchers, actively involved in the preparation of the Action, and of young researchers. Specific actions to support gender balance, as well as the involvement of young scientists, are described in section E.4.

Particular attention will be devoted to the pedagogical dissemination of the activities and deliverables of the Action within the school target group (teachers, school pupils and young students) and, more generally, among the general public.
This is a project on fundamental Science without direct technical application, but impact on industry and society stems from training highly skilled people in independence, in the capacity of solving complex problems and leading a team in a highly competitive international environment. Policy-makers will be supported by this Action in promoting scientific culture and, more specifically, in finding concrete policies to improve the participation of women in Science.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

For over forty years String Theory (ST) has provided a rich physical and mathematical framework for most of the frontline explorative research in the broad area of theoretical physics. Despite undisputable achievements, there are still fundamental open questions. This Action aims at addressing some of these questions. According to part B.2, the scientific activity will be organized into three main topics, each corresponding to a Working Group (WG).
WG1: Gauge/Gravity duality. AdS/CFT is one of the most innovative ideas in theoretical physics in the recent past. Besides being a very fertile approach to tackle the strong coupling regime of Quantum Field Theory (QFT), it has also inspired new ways in looking at the fundamental properties of QFT and gravity. A central task of this Action is to further study both fundamental and applied aspects of the correspondence.
A major problem in QFT is how to determine all interactions among the states of the theory. In two dimensions this becomes possible when integrability, i.e. the existence of an infinite number of conserved quantities, enters the game. A very important outcome of the AdS/CFT correspondence is that integrability seems to be also a property of four-dimensional N=4 SYM and its dual ST. This opens up the possibility to determine exactly the whole spectrum of observables, as well as the first exact solution of a four-dimensional interacting quantum gauge theory. This has far-reaching consequences on the understanding of general features of QCD, the theory of strong interactions. One of the major goals of this Action is to deeply investigate and exploit the role of integrability and related duality symmetries in AdS/CFT, with the double purpose of approaching the exact solution of CFTs and, simultaneously, deepening our comprehension of the mechanisms underlying the correspondence. This will be accomplished for N=4 SYM and extended in different dimensions

to other CFTs that allow for a string dual description, for which less is known.
On more phenomenological grounds, the Action aims at studying applications of the AdS/CFT correspondence for modelling strongly coupled systems of relevance for Particle Physics and Condensed Matter in terms of weakly coupled higher-dimensional gravity theories (holographic description). This implies extending the correspondence to situations where SUSY is either partially or completely broken. One of the most important spinoffs of AdS/CFT has been the development of holographic models of QCD with mesons and at finite temperature and density. The plan of the Action is to perform a comprehensive study of the QCD phase diagram at finite density and analyze its possible exotic phases. Over the last few years holography has also been applied to strongly coupled systems in Condensed Matter. In systems undergoing a quantum phase transition the behaviour close to the critical point is governed by a CFT. It is then natural to explore this regime via the gauge/gravity duality. In this Action, holographic techniques will be applied to study the dynamics of non-Fermi liquids and strange metals, as well as topological insulators and the related renormalization group flows. More generally, this Action will develop a consistent formalism to apply holography to non-equilibrium processes and thermalization. According to the gauge/gravity duality, the description of dynamical systems at finite temperature involves Black Holes solutions. The results are expected to be relevant for describing quantum quenches in Condensed Matter Physics, as well as heavy-ion data from RHIC and LHC accelerators. Activities in this direction will be coordinated with research efforts of WG3.
WG2: String phenomenology. Despite the many successful features of ST Particle Physics models, several bottlenecks prevent a detailed and systematic application to actual Particle Physics phenomenology. ST model building faces several major interconnected challenges. First of all, current string models require refinement to match observed interactions and reproduce correctly the quark and lepton flavour structure. Secondly, generic ST models realize SUSY breaking structures far richer than most SUSY variants of SM considered hitherto. Last but not least, ST compactifications generically contain massless fields (moduli), which should be eliminated or given a mass (moduli stabilization) since, otherwise, they would produce a non-observed fifth force in conflict with observations. The ingredients providing SUSY breaking parameters and moduli stabilization are fluxes, anti-D-brane sources, stringy and non-perturbative corrections. To date, the effects of their non-trivial interplay often resist explicit quantitative analysis. An ambitious goal of this Action is to undertake a rigorous analysis of such systems and seek robust mechanisms to produce vacua with all moduli fixed and with a positive cosmological constant. The Action further aims at a systematic study of SUSY breaking patterns and their manifestation in the SM sector. This may be key to unveiling the ultra-high energy regime of Particle Physics upon eventual

experimental discovery of SUSY at the LHC.
ST can also lead to models with SUSY breaking at high-energy scales (well above the TeV scale).
A challenging goal of this Action is to develop model-building tools beyond SUSY, which will lead to a more rigorous formulation of alternative scenarios for TeV scale physics. Studies in top-down scenarios of Beyond the Standard Model (BSM) physics will include, besides the Higgs sector and symmetry breaking patterns, new massive vector bosons in the form of Z' bosons or dark photons with discovery potential at the LHC and smaller accelerators. The analysis of potential dark matter candidates emerging from these models will also be a major goal.
All previous tasks imply a refinement of the present ST model building. Synergies with the activities of WG1 will be crucial in developing techniques required for this purpose. The scrutiny of moduli stabilization will overlap with the research efforts of WG3.
WG3: Cosmology and Quantum Gravity. String Cosmology is the only existing framework where a comprehensive view of the origin and evolution of the Universe can be achieved within a consistent theory valid at all scales – from the tiniest primordial quantum fluctuation, to the largest cosmological horizon distances. This Action has the ambitious goal to address the two grand challenges in this field: inflation and Black Hole physics.
A *conditio sine qua non* for ST to stand as the correct theory of the Universe is to understand how cosmic inflation and late-time acceleration can arise within string vacua. This Action will explore how to realize such features in a consistent and calculationally controllable manner. This involves understanding the mechanisms of moduli stabilization. Research activities in this direction will be coordinated with the work plan of WG2. Another task of this Action is to extract phenomenological consequences that could discriminate among different models once compared with upcoming observations, notably of the Cosmic Microwave Background by the Planck satellite. This represents by now the best chance of experimentally verifying ST in the coming years. It also provides a window onto new physics that is complementary to the physics in the reach of LHC.
The study of Black Holes is one of the main avenues to understand Quantum Gravity. Research in this field has focused not only on realistic Black Holes that might be found in our Universe, but also on more general ones appearing in higher-dimensional Supergravity theories. The intensive research over the last fifteen years is still far from exhausting the richness of the phenomena that these objects exhibit, both at the classical level and in their microscopic string-theoretical description. An important task of this Action will be to gain a more general understanding of their properties, in particular at the microscopic level.
Theoretical research on Black Holes has led to the formulation of the holographic principle, according to which some of the dimensions of space are not fundamental but emergent. This has

become the cornerstone of any effort to understand Quantum Gravity in a manner consistent with the predictions of General Relativity at large scales. At the moment, the most precise implementation of the holographic principle is the AdS/CFT correspondence, which has revolutionized the way to formulate the emergence of space-time, both at the technical and the conceptual levels. This Action will exploit the AdS/CFT correspondence and novel mathematical tools like Supergeometry to explore the breakdown of classical space-time and its emergence from more fundamental notions of holography, quantum entanglement and information. Research activities in this direction will be coordinated with the work plan of WG1.

D.2 Scientific work plan methods and means

The scientific work plan will be organized into three WGs, reflecting the topics described in Section D.1. Coordination among the three WGs, mainly focused on knowledge transfer and exchange of technical tools, will be sustained by a fourth WG, which will be responsible for the implementation of cross-WG research activities, as detailed below. With the complementary expertise present in the different countries, far-reaching synergetic effects are expected to arise from intensified exchange.
WG1: Gauge/Gravity duality. The aim is to further investigate both fundamental and applied aspects of the AdS/CFT correspondence. The scientific work plan includes:

- All loop evaluation of 3-point functions for N=4 SYM and for three-dimensional Chern-Simons-matter theories (ABJM-type models), as a fundamental ingredient for reconstructing the whole spectrum of interactions at quantum level.

Systematic study and interpretation of dualities among correlation functions, scattering amplitudes and Wilson loops from both sides of the correspondence, for N=4 SYM and ABJM-type models.

- Exploration of the novel duality between Higher Spin Theories in AdS4 and the O(N) vector model in three dimensions.

- Comprehensive study of the phase diagram of QCD at finite density and of its exotic phases.

- Study of strongly coupled matter systems at finite temperature and density, in particular by novel gravity solutions. Applications to the quark-gluon plasma: energy loss of heavy quarks, impact of magnetic fields and parity violation.

- Construction of dual models for the dynamics of non-Fermi liquids and strange metals. Study of their transport properties and pattern of phase transitions.

- Systematic study of time-dependent systems in asymptotically Anti-de Sitter spaces, dual to non-equilibrium systems.

Methods and means to achieve these objectives:

- Use of the holographic description of strongly coupled systems as derived from AdS/CFT.

- Use of well-established mathematical tools in CFT in different dimensions.

- Exploitation of novel computational techniques (including spin-chain techniques) for determining the spectrum of anomalous dimensions of composite operators, correlation functions and scattering amplitudes in N=4 SYM and ABJM-type models.

- Development of algebraic and numerical algorithms for solving higher-order loop integrals.

- Development of adapted mathematical tools for solving partial differential equations arising in the holographic formulation of time-dependent systems.

- Exploitation of string compactification techniques to construct new Black Hole solutions dual to strongly coupled systems (cross-activity with WG2,WG3).

- Development of new efficient tools for the computation of thermodynamic properties of Black Holes, to describe thermalization in QFT (cross-activity with WG3).

WG2: String Phenomenology. The aim is to further develop a more detailed and systematic application of ST models to actual Particle Physics phenomenology. The scientific work plan includes:

- Understanding flavour physics (e.g. quark and lepton masses and mixing angles) in string models via geometric and worldsheet CFT tools.

- Systematic study of non-geometric backgrounds in ST, both to generate the SM spectrum, and to address generalized stringy flux compactifications.

- Computation of brane instanton effects in D-brane and F-theory models, with bulk fluxes and gauge brane sectors, and analysis of their role in moduli stabilization.

- Computation of the backreaction of SUSY breaking terms to improve the construction of SUSY breaking meta-stable configurations in ST.

- Detailed study of Higgs sectors in SM constructions in ST, and search for relevant ingredients driving the Higgs mass to the experimentally measured value.

- Investigation of the potential of non-SUSY particles such as axions and abelian gauge symmetries as dark sector components.

- Identification of BSM collider signals within ST such as Z' bosons or light string resonances.

Methods and means to achieve these objectives:

- Use of generalized geometry and differential algebraic geometry in compactification setups.

- Use of traditionally heterotic tools in D-brane and F-theory brane model building.

- Use of D-brane geometric intuition to gain insight in heterotic model building, in particular in processes involving spontaneous breaking of gauge symmetries at one-loop.

- Improvement of computational techniques for Yukawa couplings in string models via geometric and worldsheet CFT tools (cross-activity with WG1).

- Improvement of moduli stabilization mechanisms (cross-activity with WG3).

WG3: Cosmology and Quantum Gravity. The aim is to investigate how to obtain consistent inflationary models from ST and study the physics of Black Holes as a window to Quantum Gravity. The scientific work plan includes:

- Systematic search for de Sitter vacua without tachyons and stable inflationary trajectories suitable for slow roll inflation.
- Study of the role of the inflaton in SUSY breaking during inflation and analysis of the relation between the inflationary scale and the SUSY breaking scale.
- Identification of detectable imprints of moduli and other heavy relics in the primordial perturbations.
- Classification of multi-field models of inflation derivable from ST and Supergravity and identification of their generic features.
- Understanding the likelihood and the properties of cosmic strings in string inflation models.
- Study of controlled time-dependent ST setups and time-dependent aspects of Black Holes, including the stability of both Black Holes and branes as a window onto new phases and into the formation of naked space-time singularities.
- Further analysis of extremal non-BPS Black Holes and construction of new configurations with novel types of horizon geometries and topologies in arbitrary space-time dimensions.
- Microscopic state counting of non-extremal Black Holes based on the identification of conformal symmetries.
- Development of a quantitative description of the breakdown of classical physics near or inside a Black Holes and of the information paradox.
- Exploration of holography, entanglement, and the emergence of space and time in space-times that are not asymptotically anti-de Sitter, like Rindler and de Sitter space-times.
- Study of the structure of super space-time and its transition to the quantum phase.

Methods and means to achieve these objectives:

- Exploitation of moduli stabilization techniques (cross-activity with WG2).
- Exploitation of string compactification techniques to construct new Black Hole solutions also relevant for physical systems at finite temperature (cross-activity with WG1).
- Exploitation of effective theory methods to explore the phase space of Black Hole solutions and their stability properties.
- Use of the AdS/CFT correspondence to understand the emergence of semi-classical space-time.
- Use of the holographic principle as derived from AdS/CFT (cross-activity with WG1).

E. ORGANISATION

E.1 Coordination and organisation

“The String Theory Universe” is a concerted Action of different partners that will support maximal coordination of local research activities, interaction and cooperation among, mainly, European researchers. The Action organization will conform to the COST document “Rules and procedures for implementing COST Actions”.

(a) Management

1. Management Committee (MC). The Action will be governed by the Management Committee and chaired by a Chair-person, assisted by a vice-Chair, both elected during the kick-off meeting.

2. Core Group (CG). A Core Group within the MC will be established in order to render the management more rapid and efficient. It will be composed by the Chair, the vice-Chair, the Working Group Leaders (see E.2) and the Coordinator of Job Opportunities. The CG will be responsible for the preparation of all documents required for MC meetings.

3. STSMs manager. The Leader of WG4 will function also as STSMs manager within the CG and MC. She/he will prepare the annual plan to be submitted to the MC.

4. Gender and outreach Coordinator. The Leader of WG5 will function as gender balance Coordinator as well as Outreach Coordinator within the CG and MC.

5. Coordinator of Job Opportunities. A Coordinator of job opportunities offered by the Action Parties will be assigned by the MC. Progress in this activity will be reported to the MC.

(b) Scientific Coordination and Networking

Scientific coordination and networking will be achieved through:

1. Workshops and Training Schools. One annual Workshop will be organized together with two Training Schools throughout the duration of this Action. The Action activities will be finalized by an international conference held in Brussels. WG4 will coordinate the organization of these activities.

2. Training courses and seminars. Organized locally by single parties in connection with STSMs funded by the Action. They will be available to all parties through the Action Website.

3. Scientific Strategic Meeting. A mid-term scientific meeting will be organized among the five WGs and open to all participants in the Action, aimed at discussing the main scientific and organizational achievements and future plans.

4. Coordination of Job Opportunities. Action Parties may decide to coordinate the recruitment of postdoctoral researchers using a common platform made available within the Action. A Coordinator will be responsible for collecting information, advertising on the Action's Website and organizing the application and ranking procedures. A list of best applicants will be available annually to all parties, in order to facilitate their own recruitment procedure.

5. Establishment of a Website. A Website will be created in line with the COST Office requirements. General introduction to the Action, information about partner groups, research activities, workshops, training schools, training courses and seminars, job opportunities, gender forum, and forthcoming events will be included.

(c) Milestones

The Action will run for four years. The main milestones are:

YR	MILESTONES	DELIVERABLES
1	Month 1: Kick-off meeting: MC, CG, WGs are set up, Work-Plan established. Month 9: MCM 1; WGM; Workshop 1. Month 12: Job opportunity meeting 1.	Website fully operational, WGs reports, Annual Report, GOJ activities, Scientific publications, Workshop1
2	Month 14: MCM 2; WGM; TS 1. Month 21: MCM 3; WGM; Workshop 2.	WGs reports, Annual Report, GOJ activities, Scientific publications,

	Month 24: Job opportunity meeting 2.	TS 1, Workshop 2
3	Month 26: Scientific Strategic Meeting; WGM Month 33: MCM 4; WGM; Workshop 3. Month 36: Job opportunity meeting 3.	WGs reports, Annual Report, GOJ activities, Scientific publications, Workshop 3
4	Month 38: MCM 5; WGM; TS 2. Month 45: MCM 6; WGM; Final conference. Month 48: Job opportunity meeting 4.	WGs reports, Annual Report, GOJ activities, Scientific publications, TS 2, Final conference

MCM: Management Committee Meeting, WGM: Working Groups Meeting
GOJ: Gender, Outreach, Job opportunities, TS: Training School

E.2 Working Groups

The Action scientific plan will be implemented by three working groups: WG1, WG2, WG3, as described in Section D. WG4 will promote cross-activities and exchange of knowledge among the three working groups, will coordinate the STSMs and the organization of Workshops, Training Schools, joint seminars and training courses for ESRs. It will include at least one representative of WG1, WG2, WG3 and WG5. WG5 will be responsible for gender issues and outreach activities, according to the plan described in sections E.4 and H. It will also include at least one representative from WG1, WG2 WG3 and WG4. Within each Working Group a WG-leader and a vice-WG-leader will be appointed by the MC.

E.3 Liaison and interaction with other research programmes

Some of the members of this Action are also involved in other research programmes (see section B.4). They will foster the organization of common workshops, invitations of speakers to the Action workshops and schools, short-term scientific visits and scientific collaborations. Particular attention will be paid to the crossed mobility of young researchers.
Gender issue activities will be tuned with the ongoing activities of the Genis Lab project, a "support action" funded by the European Commission within the 7th Framework Program, which includes

scientific partners with expertise in gender mainstreaming tools from some of the COST countries participating in this Action.

E.4 Gender balance and involvement of early-stage researchers

This COST Action will respect an appropriate gender balance and considerable involvement of early stage researchers (ESR) in all its activities and the Management Committee (MC) will place this as a standard item on all its MC agendas. An innovative aspect of this Action is that there will be a Working Group dedicated to the issue of the low rate of women's involvement in Physical Sciences. WG5 will:

- Promote active participation of women scientists within the network. Particular attention will be paid to ensure the presence of highly qualified women in scientific committees, in postdoctoral selection procedures and as speakers in Workshops and Training Schools. Both highly qualified senior as well as outstanding young female researchers will thereby act as role models for subsequent generations.

- Monitor the adequate valuation of outstanding female researchers and ensure that their talent is given the proper visibility.

- Identify best practices across Europe for redressing the strong gender imbalance in this field, for example by publicising the impact of dedicated Ph.D. scholarships to outstanding young female researchers, which are awarded at some Universities on a competitive basis.

- Promote closer collaborations between schools and universities to create positive images of women in Science and present role models.

- Organize scientific outreach activities at universities (colloquia, seminars) in order to encourage younger women to pursue doctoral studies in theoretical physics.

- Mentor and support young women at the beginning of their scientific careers through a dedicated forum on the Action Website and informal meetings of all female participants held during Training Schools and Workshops of the Action.

- Monitor constantly the growth of the scientific female community in the field by collecting data on the number of female participants in Training Schools and Workshops and the number of female lecturers and seminar speakers.

These activities will be mostly handled by women researchers participating in the Action.
The Action will be committed to providing high-level cross-disciplinary education to ESRs. All participating units have long-standing experience in doctoral training. The Action will provide additional means in educating rounded students with a wide area of expertise and interdisciplinary competences. Specific tools will be:

- Collaboration between experienced researchers and ESRs at all levels, including devolving management tasks and outreach activities to ESRs.

- Participation of ESRs in the WG meetings, workshops and conferences.

- Training Schools and Workshops that will expose ESRs to the current research activities and open scientific problems. ESRs will be encouraged to present communications and participate in their organization.

- STSMs mainly focused on promoting the mobility of ESRs.

F. TIMETABLE

ACTIVITY	**YEAR 1**				**YEAR 2**				**YEAR 3**				**YEAR 4**			
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
WG1	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WG2	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WG3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WG4	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WG5	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Other Activities																
Kick-off meeting	●															
Establish MC,WGs	●															
Establish WorkPlan	●															

Set up of Web Site		●														
MC, WG meetings				●	●			●				●	●			●
JO meetings				●				●				●				●
SSM									●							
Workshop				●				●				●				
Training School								●					●			
Final conference																●
Gender issue act.				●	●	●	●	●	●	●	●	●	●	●	●	●
Outreach act.				●	●	●	●	●	●	●	●	●	●	●	●	●

JO: Job Opportunities SSM: Scientific Strategic Meeting

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: BE, BG, CH, DE, DK, EL, ES, FR, HU, IL, IT, NL, PT SE, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 60 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

The Action will foster collaboration also with Non-COST countries and European bodies. South Africa is already actively involved, and groups in USA, Chile, Argentina and Brasil have expressed their strong interest in participating.

H. DISSEMINATION PLAN

H.1 Who?

The MC, assisted by a dedicated working group (WG5), will be responsible for the dissemination strategy of the Action, which will be targeted to two main groups. The first one is formed by the

broad high-energy-theory scientific community, which includes scientists, young researchers and PhD students active in String Theory as well as in related areas (as for example Condensed Matter theory, Cosmology, Particle Physics phenomenology and pure Mathematics), Universities and Research Institutions joining this Action and other networks and cooperation projects at European or national levels (also in participating Non-COST countries).
The second group is external to the scientific community. This includes scientific policy makers, funding agencies at European and national levels, the media (press, internet), school pupils, high school students and teachers, and the general public.
The MC will monitor that the material is adapted and fully adequate to the specific needs of the various target audiences.

H.2 What?

The dissemination plan includes several methods appropriate to each of the audiences.

1) The MC will oversee the work of WG5 in the setup of a dedicated Website for the COST Action containing three different levels:

- A password protected area with information available to the MC.
- An area for scientists with a publication database, information about activities and events, and the management structure of the Action.
- An area directed to the general public. This will be designed to communicate in a non-technical (but accurate) language the aims and outcome of the Action, and more generally to attract the general public towards the most fundamental questions concerning the microscopic world of elementary particles and the origin of the Universe. A special forum will be dedicated to important social implications of this Action, mainly the problem of the involvement of women and young generations in Science.

2) There will be an appropriate follow up of all the scientific publications (articles in peer-reviewed journals, books, contributions to books, proceedings) produced by the members of the Action. This is targeted to scientists and constitutes the main body on which the dissemination strategy relies.

3) Also targeted to scientists and PhD students (of the field or related fields) are the Training Schools, Workshops, Conferences, seminars and training courses organized by the Action and the STSMs.
4) Special attention will be paid to the dissemination among the general public. This will be supported by specific outreach activities for school pupils, non-technical talks in high schools and cultural circles, divulgation articles and press releases.
5) Finally, the Action will offer to policy makers, funding agencies and also to the media, information about the scientific functioning of the Action, as well as its involvement in social issues.

H.3 How?

The Website will be the main tool for the dissemination strategy, directed to the three levels (MC, scientists and general public). As a vital point concentrating all the information regarding the Action, it will include:

- Information on the management of the Action, collecting scientific reports, lists of works in progress, financial reports, minutes and information about MC and WG meetings.

- Mailing lists for the committees and members of WGs that will allow coordination and information exchange at each level.

- The periodically updated list (with links) of the scientific publications (peer reviewed articles, books, contributions to books, proceedings).

- All the information of past and upcoming events both of this COST Action and worldwide (Workshops, Conferences and Training Schools), which are relevant to scientists inside and outside the Action.

- All the information about weekly seminars held in the Action’s Institutions, possibly making them available on the Website, via teleconference.

- All the information about training courses for ESRs.

- Articles, book reviews, and information of events that are of interest to the general public. A forum will be set up to encourage the general public to participate asking questions about ST and interacting with the scientists.

- Information about the social issues regarding women in Science and young researchers. These are highly relevant for the Action.

- A space for offering young scientists the best visibility within and outside the Action.

The events and scientific exchanges organized by the Action are the natural route of dissemination among scientists, bringing them together to discuss recent progresses and new ideas. The MC will encourage the participation of scientists outside the Action and working in closely related areas, which will create invaluable synergies and expand its horizon. Also, an important ingredient in each major event will be a talk for the general public, delivered by a prestigious scientist, presenting in a common language the ideas, results, puzzles and challenges that string theorists face every day.
The MC will setup encounters with policy makers and funding agencies to discuss and inform about scientific progress, best practices to improve the efficiency, needs and problems that scientists, especially women, face in their working environment. Also, the Action will monitor and inform on the progression of young scientists in their careers and offer ideas to improve their situation in a highly competitive frontier research environment.