

Advisory Committee Session
Crete, 20-22 July 2012

*Crete Center for Theoretical
Physics*

Plan

- The European Capacities Project
- The Physics Department
- The center and its Personnel
- The Physics

The European Capacities Project

- The REGPOT program of the European Capacities framework aims at giving a one-time-grant support to high-quality research teams of the "periphery" of Europe, in order to help them compete and become comparable top good teams of the most advanced areas in Europe.
- The proposal CreteHEPCosmo for "Crete Center for Theoretical Physics" was evaluated in the 2008 round of proposals, and finished first among all proposals (about 300 in all sciences) with a perfect score (15/15).
- It involves 1,120 kEuros over period of 3 years. It officially started in 1/4/2009. Its duration was extended and it ends August 31st, 2012.
- It involves 5 Work-packages each with a different focus.

- Hiring of a 3-year senior research fellow. Position offered to Marika Taylor that eventually declined. Offered to **Vasilis Niarchos (Ecole Polytechnique)** that accepted and started in 1/7/2010-31/8/2012 (26 months). He is staying in CCTP for another 3 years after the end of this program.
- Hiring of several postdoctoral research fellows. Positions advertised in 2008. Hired in the first round:

Rene Meyer (PhD Munich, 1/10/2009-31/8/2012, 35 months, goes to IPMU, Tokyo after this),

Matthew Lippert (PhD Santa Barbara, 1/9/2009-31/8/2012, 36 months, goes to Amsterdam after this)

Hong Bao Zhang, (PhD Beijing University, 1/10/2009-31/8/2012, 35 months, goes to Vrije Universiteit Brussels after August),

Several new positions became available in 2009 and were advertised. The following researchers were hired

Takeshi Morita, (PhD, Yukawa Institute Kyoto, 1/9/2010-31/3/2012, 20 months, went to KEK, Japan),

Matti Jarvinnen, (PhD University of Helsinki, 1/9/2010-31/8/2012, 24 months. Remains at CCTP for 2 extra years on a Marie Curie individual fellowship)

Tassos Taliotis (PhD, University of Ohio, 1/4/2011-31/8/2012, 17 months. Goes to to Vrije Universiteit Brussels after August)

Pavel Spirin (PhD, Moscow State University, 1/9/2010-30/4/2011, 8 months. Went back to Moscow State University)

Several short term fellows were appointed in the last year with leftover funding:

Andrew O'Bannon, (PhD University of Washington, Seattle, 1 month, went to Cambridge afterwards).

Ioannis Papadimitriou, (PhD Princeton-Amsterdam, 1 month, went to Madrid afterwards).

Umut Gursoy, (PhD MIT, 1 month, went to CERN afterwards).

Blaise Gouteraux, (PhD Orsay, 1 month, went to APC afterwards).

Daniel Arean. (PhD Santiago de Compostela, 1 month, went to SISSA, Italy afterwards.)

Liuba Mazzanti, (PhD Milano-Ecole Polytechnique, 1 month, went to Santiago de Compostella afterwards).

- The CCTP advertised postdoctoral positions and received application via a common central website that it helped founding several years ago with several European partners, based in Leuven, Belgium.
- Around 20 top European groups of the field participate in this website (with some notable absences).
- The applicants present an ordering of the 5 most preferred institutions/groups and they also answer if they want to be considered for the rest.

The following data of preferences are relevant:

- In 2008/2009 round, there were 354 application. CCTP was second in first preferences of the applicants with 62, following Imperial with 68 and ahead of Munich, Saclay, NBI, Utrecht, Ecole Polytechnique, ULB, Universita Autonoma de Madrid, Bonn Univ., KU Leuven, VUB, Milano and Patras.

- In the 2009/2010 round, there were 400 applicants. CCTP was fourth in first preferences of the applicants with 35, following Amsterdam (78), Munich (65) and Saclay (43) and ahead of Utrecht, Barcelona, NBI, SISSA, ULB, Ecole Polytechnique, IHES Paris, VUB, Weizmann, Bern, Leuven, Milano, Groningen, Jerusalem.
- In the last round that CCTP participated, this year (2011/2012), there were 405 applicants and CCTP ranked 3rd from last, only ahead of Groningen and Torino. Imperial, Munich, Saclay, Utrecht, Barcelona, SISSA, Leiden, Copenhagen, Weizmann, Milano, Bern and VUB ranked ahead.
- It is clear that "the Local crisis" has affected adversely the will of young researchers to come and work in Crete.

- **Developing a small scale computational facility:** 15 processors have been bought and installed along with a server and a switch. the cluster has been operational and used since 2009.
- **Developing the local infrastructure for hosting extra researchers.** Various infrastructure items were bought in order to prepare the spaces for hosting the researchers and visitors.

Work-package 2: Personnel exchanges and twining

- The purpose of this work package is to establish research connections and to support exchanges between the Center and several high quality European institutions. In particular this includes
 - **Outgoing visits** by the Center members to these institutions
 - **Incoming visits** of researchers of such institutions (or others if there is an incentive)
- The development of more formalized relations with such institutions if appropriate, at the level of closer collaboration in research exchanges, organization of events and eventually education, via MoUs.

1. **Laboratoire de Physique Théorique de l'Ecole Normale Supérieure, Paris**
C. Bachas, C. Kounnas, V. Kazakov, G. Policastro, J. Troost, A. Kashani-Poor
2. **Theory Group, Università de Roma II, Tor Vergata**
M. Bianchi, F. Fucito, T. Vladikas, E. Pradisi
3. **Arnold Sommerfeld Institute, Max Planck Institute, Munich**
D. Lust, S. Mukhanov, G. Dvali, R. Blumenhagen, J. Erdmenger, S. Stieberger, M. Haack
4. **Physics Division, CERN, Geneva**
I. Antoniadis, L. Alvarez Gaume, G. Dvali, C. Grosjean, A. Uranga, J. Wells, U. Wiedemann
5. **Institute for Theoretical Physics, University of Amsterdam.**
E. Verlinde, J. de Boer, K. Skenderis, J P. Van der Schaar, K. Schalm, M. Taylor
6. **Department of Applied mathematics and Theoretical Physics, University of Cambridge.**
F. Quevedo, A. Davis, N. Dorey, M. Green, G. Gibbons, P. Shellard, P. Townsend, D. Tong
7. **Theory group, Imperial College, London.**
K. Stelle, A. Hannany, C. Hull, J. Gauntlett, A. Tseytlin, D. Waldram, T. Wiseman
8. **Center of Excellence, Hebrew-Weizmann-Tel Aviv.**
E. Rabinovici, A. Giveon, J. Sonnenschein, Y. Oz, N. Itzhaki, O. Aharony, M. Berkooz, A. Schwimmer, B. Kol, G. Lifshytz, O. Bergman, R. Brustein
9. **Laboratoire d'Astroparticule et Cosmologie (APC), Paris.**
S. Katsanevas, P. Binetruy, C. Deffayet, D. Langlois, J. Mourad, F. Nitti, D. Steer.

Twining agreements were eventually signed with:

- Amsterdam ITF,
- APC, Paris,
- ENS, Paris
- LMU, Munich
- Israel HEP Committee

as well as another institution not in the list

- Solvay Institute, Brussels (involving ULB, VUB)
- There were numerous outgoing and incoming visits that were funded by the program. These were instrumental in creating contacts, bringing in expertise and supporting an active weekly seminar and making our work known to our partners.

Crete Center for Theoretical Physics,

Work-package 3: Organization of meetings

- This is an important part of the project that aims at the organization of conferences and workshops locally. The purpose is to bring in expertise, and make the Center known to outside researchers.
- Two workshops and a conference were initially planned.

● **A Workshop on the Frontiers of Cosmology** (Heraklion, 28 March-5 April 2010)

Crete Workshop on the Frontiers of Cosmology

<http://hep.physics.uoc.gr/cosmo10/index.html>

**Crete Workshop
on the Frontiers of
Cosmology**

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**Crete Center of Theoretical Physics
Heraklion
28 March-5 April 2010**

(28 March is arrival day, 5 April is departure day)



International Organizing Committee	Local Organizing Committee
<ul style="list-style-type: none"> • P. Binetruy (APC, Paris) • B. Craps (VUB, Brussels) • G. Dvali (CERN) • G. Gibbons (Cambridge) • C. Kounnas (Paris) • S. Mukhanov (LMU, Munich) 	<ul style="list-style-type: none"> • E. Kiritsis (U. of Crete) • G. Kofinas (U. of Crete) • T. Petkou (U. of Crete) • T. Tomaras (U. of Crete) • N. Tsamis (U. of Crete) (chair)



Project CreteHEPCosmo

- 25 external participants,
- 11 CCTP participants,
- participation by invitation,
- 2 overview talks per day, with extended discussion time.

Topics discussed: Dark Matter, Small field models of Inflation, Bouncing Cosmologies, Hořava-Lifshitz gravity, Gravitational Waves, Modified gravity theories, Primordial spectrum non-Gaussianity, Alternative theories of gravitation, Holographic Inflationary Correlations, Cosmological Singularity resolution.

- A Conference on Gauge theories and the structure of spacetime (Kolymbari, 10-17 September 2010)

Crete Conference On Gauge Theories And The Structure Of Spacetime

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**The Orthodox Academy of Crete
Kolymvari, Crete**

11-18 September 2010

(11 is arrival day, 18 is departure day)



International Organizing Committee	Local Organizing Committee
<ul style="list-style-type: none"> • L. Alvarez-Gaume (CERN) • I. Antoniadis (CERN) • C. Bachas (Paris) • M. Bianchi (Roma) • D. Lust (Munich) • F. Quevedo (Cambridge) • E. Rabinovici (Jerusalem) • K. Skenderis (Amsterdam) • K. Stelle (Imperial) 	<ul style="list-style-type: none"> • E. Kiritsis (U. of Crete) • G. Kofinas (U. of Crete) • V. Niarchos (U. of Crete) • T. Petkou (U. of Crete) • T. Tomaras (U. of Crete) (chair) • N. Tsamis (U. of Crete)

- 6 review talks: Heckman (F-theory Model Building), S. Hartnoll (Holography and Condensed Matter physics), D. Jafferis (3d Holography), Myers (Holographic c-theorems), Korchemsky (sYM amplitude calculations), Kazakov (integrability in sYM).
- 73 outside participants
- 14 CCTP members.

- Workshop: “Gravity Theories and their avatars”, 13-19 July 2012 (in Heraklion)

Gravity Theories and their Avatars

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**Crete
Center of
Theoretical
Physics
Heraklion
13-19 July
2012**

*(12 July is arrival
day, 20 July is
departure day)*



International Organizing Committee	Local Organizing Committee
<ul style="list-style-type: none"> ● O. Aharony (Weizmann, Israel) ● C. Bachas (ENS Paris, France) ● M. Bianchi (Rome U., Italy) ● J. Gauntlett (Imperial, UK) ● M. Henneaux (Brussels) ● D. Lust (Munich U. ASC, Germany) ● K. Skenderis (Amsterdam, Netherlands) ● J. Sonnenschein (Tel Aviv, Israel) 	<ul style="list-style-type: none"> ● E. Kiritsis (U. of Crete) ● V. Niarchos (U. of Crete) (chair) ● T. Petkou (U. of Crete) ● T. Tomaras (U. of Crete) ● N. Tsamis (U. of Crete)

- 12 keynote speakers
- 37 external participants,
- 13 CCTP participants,
- 2 overview talks per day, with extended discussion time.

Topics discussed: Mostly topics related to the AdS/CFT correspondence and its various applications to the physics of finite density.

♠ As there were leftover funds from this workpackage permission was obtained to use them to partly support two more meetings:

- Workshop “Regional Meeting on string theory”, 19-26 June 2011 (in Milos)

SIXTH CRETE REGIONAL MEETING IN STRING THEORY

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[Milos Conference Center](#)
George Eliopoulos,
June 19 - June 26 2011

(19 June is arrival day, 26 June is departure day)



International Organizing Committee

- F. Ardalan (IPM, Teheran)
- I. Bakas (U. of Patras)
- E. Kiritsis (U. of Crete)
- K. Narain (ICTP, Trieste)
- E. Rabinovici (Hebrew U., Jerusalem)
- S. Wadia (ICTS and Tata I., Mumbai)
- E. Witten (IAS, Princeton)

- 61 external participants mainly from Greece, Israel, Iran and India
- 13 CCTP participants.
- High quality meeting including all top physicists from these countries, as well as a few external keynote participants (Strominger, Lust, Jafferis).

- “6th Aegean School on Quantum Gravity and Quantum Cosmology”, 12-17 September 2011 (in Naxos)

SIXTH AEGEAN SUMMER SCHOOL
QUANTUM GRAVITY AND QUANTUM COSMOLOGY

Chora, Island of Naxos 12-17 September 2011

Last Minute Info **NEW!**

General Information

Organizing Committee

Participants

Scientific Program **NEW!**

Travel and
Accommodation **NEW!**

Map of Naxos

Registration

History

Lecture Notes in Physics

Best cited articles of the
Aegean Schools



- 91 students (PhD's and postdocs)
- 12 lecturers
- 6 CCTP participants
- Covered various approaches to the quantization of Gravity (string theory, loop quantum gravity, asymptotic safety) as well as quantum gravitational effects in cosmology.

- The role is to advise us on science and science policy and to evaluate the evolution of the project.

Members are highly distinguished physicists.

- **Curtis G. Callan Jr** is since 1995 James S. McDonnell Distinguished University Professor of Physics at Princeton University, founding director of the Princeton Center for Theoretical Physics (2005-2008), has been chairman of the Physics Department and is currently vice president of APS. He is the recipient of the Sakurai prize for physics (2000) and the 2004 Dirac Medal.
- **John Iliopoulos** is directeur de Recherche au CNRS, (classe exceptionnelle) at the Laboratoire de Physique Théorique, Ecole Normale Supérieure and a member of the French Académie des Sciences. He is the recipient of the Sakurai prize in Physics (1987), the Dirac Medal (2007) and the EPS HEP prize (2011).
- **Gabriele Veneziano**, is a senior staff member at the CERN theory group and holds the chair of particle physics and cosmology at the College de France since 2004. He is the recipient of the I. Ya. Pomeranchuk prize (1999), the Enrico Fermi Prize (2005) and the Danny Heinemann prize (2004).

Finally there is an additional work-package devoted to the management of the project.

The Physics Department

- The Physics Department of the University of Crete was founded in 1978.
- It has 29 faculty members, 5 emeriti, 1 Distinguished professor, 12 technical and administrative personnel, 14+34=48 postdoctoral research fellows, 33 Master's students and 29 PhD students.
- It has close ties and collaboration with the nearby Foundation for Research and Technology Hellas (FO.R.T.H) (A European Laser Facility).
- The Physics Department is the top of its kind in Greece. It was the first in Greece (1984) to have organized graduate studies (all other universities followed suit in the late nineties following pressure from the EU), a curriculum on a par with modern standards, and to cultivate high-quality experimental research (a subject from difficult to impossible in countries like Greece).
- the research areas that are represented involve
 - ♠ High Energy Physics and Cosmology (theoretical)
 - ♠ Astrophysics (theoretical and observational)
 - ♠ Condensed matter physics (Theoretical and experimental)
 - ♠ Applied physics and material science (Mostly experimental)
 - ♠ Atomic physics and Lasers (theoretical and experimental)
 - ♠ Others (atmospheric physics, plasma physics, accelerator physics etc)

Crete Center for Theoretical Physics,

The Crete Center for Theoretical Physics

- It is a structure emerging from the recent European Grant which we are trying to consolidate.
- The underlying unit is the section of the Department associated to high energy physics (initial and official name : "particle and nuclear physics")
- Faculty in order of arrival date:

George Grammatikakis (PhD Imperial, 1973) Emeritus, Experimental high Energy physics

Petros Ditsas (PhD Manchester 1976), recently retired, theory, phenomenology of particle interactions.

Nikos Papanicolaou (PhD NYU, 1975) currently working on spin models, high T_c superconductivity, topological defects in condensed matter etc.

Theodore Tomaras (PhD Harvard, 1980), currently working on gravity and cosmology

Elias Kiritsis (PhD Caltech, 1988) currently working on string phenomenology, AdS/CFT and cosmology.

Nikolas Tsamis (PhD Harvard, 1983) currently working on quantum effects in gravity and inflation.

Anastasios Petkou (PhD Cambridge, 1994), currently working on the AdS/CFT correspondence (soon moving to University of Thessaloniki).

and

Dimitris Christodoulou (PhD Princeton, 1971), Distinguished Professor of Physics.

- Affiliated members (frequent visitors/collaborators, other disciplines)

Petros Rakintzis (Atomic Physics, Physics Department, Crete)

Christos Panagopoulos (Condensed matter, Physics Department, Crete)

Ioannis Bakas (Mathematical Physics, Athens Polytechnic School)

Costas Skenderis (Amsterdam University)

Marika Taylor (Amsterdam University)

Richard Woodard (U of Florida)

Nicolas Toumbas (U of Cyprus, recently elected associate professor in the Physics department)

- Researchers and Postdoctoral fellows currently

Matti Jarvinnen (PhD Helsinki U.)

Matthew Lippert (PhD UC Santa Barbara)

Rene Meyer (PhD LMU Munich)

Vasilis Niarchos (PhD Chicago U.)

Tassos Taliotis (PhD Ohio State U.)

Hong Bao Zhang (PhD Beijing University)

as well as previous long term researchers since first Committee Visit

Bom Soo Kim (PhD Berkeley, now at Tel Aviv University)

Georgios Kofinas (PhD Athens, now faculty at Aegean University)

Daisuke Yamada (PhD University of Washington, Seattle, now on a carrier break)

- There are also 3 PhD students (I. Constantinou, I. Iatrakis and M. Romania), and on the average 2-4 master's students.

Crete Center for Theoretical Physics,

Networks, collaboration, Grants

- E. Kiritsis played a pivotal role in the formation of the ESF network "Holograv" and is a member of the steering committee. There is a strong participation from CCTP and other Greek scientists. This network was NOT funded from Greece.
- CCTP was awarded recently a 3-year grant from GSRT (ERC5-AdS/CMT, 1,140,000 euros). 7 ERC proposals were funded by GSRT, that made it in the second round but were not funded at the end.
- Several CCTP members have co-organized meetings abroad: A. Petkou, in GGI (Florence), N. Tsamis at Max-Planck (Hannover), E. Kiritsis: two meetings at APC, (Paris) and one at ICTP, (Trieste).

Education

- The CCTP faculty members contribute teaching to the undergraduate curriculum, as well as to the master's program. They direct undergraduate, master's and PhD theses.
- They have organized in the past, international courses attended by foreign and local students.
- Such an Intense course will be organized next Spring, in the department. It will be entitled: "Non-Perturbative Quantum Field Theory", and its purpose is to provide a training in non-perturbative techniques that are not usually taught currently in PhD programs, in tandem with Holographic techniques. It will be 100 hours long.
- All the universities of Greece as well as the Paris Doctoral program, VUB, ULB, Amsterdam, Leiden , Cambridge, Oxford, Durham, Imperial, Munich, Roma II, NBI, Uppsala U., Weizmann, Hebrew U., Tel Aviv U. will send students and recognise units for the course.

- 60 kEuro were obtained from the **Erasmus IP project** to fund the incoming students and lecturers costs.
- More than half of the teaching will be done by CCTP members.

Outreach

- CCTP organizes in the last few years the yearly “masterclasses”, whose purpose is to bring in contact high school students with High energy physics.
- Prof. Tsamis coordinates this effort that involve a pan-Cretan move of students to the Department during a day and lectures by prof. Tomaras on particle physics.
- There is a hands-on competition with other groups in Europe in real time, by connecting to CERN and identifying particle signals in accelerator data. Prof. Kourkouvelis from Atlas has importantly contributed to this effort that seems to have a high impact.
- There is a day of lectures for High-School Professors every year. Prof. Tomaras has systematically lectured in these meetings.
- Lectures at High Schools for the students (Tomaras).

- The organisation of [several public lectures for the general public](#):
- On the occasion of the 30 years of the department: [J. Iliopoulos, P. Sphicas and S. Katsanevas gave public lectures](#).
- [Dimitris Christodoulou](#) talked about Hellenistic Mathematics.
- [CERN exhibition](#). E. Kiritsis and external scientists gave public talks during the start and end of the exhibition.
- CCTP members write popular articles for high-school students or for the media.
- The [CCTP webpage on outreach](#) has many more links to other organized websites on the field.

Overview of the Physics

- **Research Direction 1:** AdS/CFT and applications.
 - 1A: Finite density and condensed matter applications.
 - 1B: Applications to QCD and Heavy-Ion physics.
 - 1C: AdS_4/CFT_3
- **Research Direction 2:** Gravity and Cosmology.
 - 2A: High-energy gravitational scattering.
 - 2B: Gravitational backreaction and quantum effects in inflation.
 - 2C: Black holes and blackfolds
 - 2D: Modified theories of gravity, (related to 3A).
- **Research Direction 3:** The physics of Lorentz violation.
 - 3A: Gravity theories of the Hořava-Lifshitz type.
 - 3B: LV in strongly coupled QFTs.
- **Research Direction 4:** String Phenomenology.

Distinctions

- Distinguished Professor [D. Christodoulou](#) was awarded the [Shaw prize for the Mathematical Sciences](#), shared with Prof. R. S. Hamilton. The prize was given for their highly innovative works on nonlinear partial differential equations in Lorentzian and Riemannian geometry and their applications to general relativity and topology.
- CCTP Postdoctoral researcher [T. Morita](#), was awarded the "Young Scientist Award of the Physical Society of Japan" for his work on the phase structure of compactified YM.
- The paper *Int.J.Mod.Phys. D20 (2011) 2847-2851* by [Tsamis+Woodard](#) received an honorable mention from the Gravity Research Foundation.
- The paper *arXiv:1204.2029 [hep-th]* by [Zhang+Wu+Tiang](#), received an honorable mention from the Gravity Research Foundation.
- The paper *Class.Quant.Grav.26:105006,2009* by [Tsamis+Woodard](#) has been highlighted in 2009 by the Journal of Classical and Quantum Gravity
- The paper *Nucl.Phys.B821:467-480,2009* by [Kiritsis+Kofinas](#) was among the 50 most cited papers in 2009. Today it has 248 citations in SPIRES.
- The papers *Phys.Rev.Lett.101:181601,2008* and *Nucl.Phys.B820:148-177,2009* by [Gursoy+Kiritsis+Mazzanti+Nitti](#) were highlighted in Physical Review Focus on the occasion of a recent high-precision lattice calculation in Large N gauge theory.

A final assesement

I feel that the REGPOT program "CreteHEPCosmo" that nears its end, did already what was intended to do, successfully.

- It has given an important impetus to our Center and has put it on the scientific map.
- Has created permanent links with several important European institutions
- It has helped in attracting qualifying scientists to Crete.
- It has opened to us new avenues for research.

The Future?

- Stability of the structure in the long-term
- Local crisis creates enormous problems of survival (Faculty salaries, University funding, suppression of faculty positions, Greek Bureaucracy, difficulties for hiring researchers etc)
- Funding sources (EU/Greece, Private foundations?)
- Faculty evolution (two positions frozen by the ministry since two years)
- Many new administrative and practical problems because of new laws that do not take into account their impact on research and research personnel.

Further Physics

- Theodore Tomaras
- Nikolas Tsamis
- Tassos Petkou
- Petros Rakintzis
- Hong Bao Zhang
- Tassos Taliotis
- Rene Meyer
- Matti Jarvinen
- Matthew Lippert
- Vasilis Niarchos

Crete Center for Theoretical Physics,

THANK YOU

1A: AdS/CMT

- This is a topic that there is a lot of expertise in the Center.
- The holography of **Schrödinger symmetric systems**, with particular focus on finite temperature transport (**Kim+Yamada**). An intriguing model for **strange metal transport** at ultralow temperatures has also been constructed that is very close to recent transport and magnetotransport experimental data, (**Kim+Kiritsis+Panagopoulos**).
- The study of **holographic fermi surfaces** in the dilatonic (EMD) backgrounds with and without bulk dipole couplings (**Zhang+Meyer+coll.**)
- **The holographic study of Hall-effect-like physics** in D-brane models. It was pioneered by Lippert and the Technion group, and involved the construction of stable models, by turning on internal fluxes, the study of excitations both standard and magnetic rotons, and the study of striped instabilities (**Lippert+Jarvinnen+ coll.**)
- The proposal and study in several papers of the **Effective Holographic Theory** asymptotics in order to classify and study low-temperature holographic physics. It involved a parametrization of the gravitational theories (EMD), finding near extremal solutions, and studying their thermodynamics and transport. In this direction, the most general **quantum critical geometries with hyperscaling violation** have been classified in the U(1) unbroken phase, and the classification in the broken phase is underway. (**Gouteraux+Kim+Kiritsis+Meyer+coll.**)
- The calculation of the refractive index in holographic superconductors (which sometimes is negative), (**Zhang+coll.**)

- The development of the **parity-violating hydrodynamic equations for a charged fluid in 2+1 dimensions** to first order in derivatives. There are special terms that were not known before, and were uncovered using holography. In this same direction, the use of action techniques to bypass the derivation of constraints emerging from the entropy current in relativistic hydrodynamics, ([Meyer+coll.](#)).
- The study of holographic fluids with vorticity in 2+1 dimensions based on the TaUb-Nut and Kerr solutions, and their potential application to rotating cold strongly coupled atom gases ([Petkou+coll.](#)).
- The development of techniques to calculate the quantum effective potential holographically at finite temperature and density. This allows the analytic study of phase transitions in scaling regimes, and the numerical study in any regime. The procedure is currently extended to the the rest of the effective action. ([Kiritsis+Niarchos+coll.](#))
- A new setup for constructing and studying couplings of holographic QFTs analytically using **multitrace deformations**. This leads to a new setup for **Josephson junctions of holographic superconductors**, that allows direct calculation of their properties and provides relativistic generalizations of the Gross-Pitaevsky equation. Many solutions here have chaotic behavior. ([Kiritsis+Niarchos+coll.](#))

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1B: Holographic QCD and Heavy-Ion physics

- The use of **IHQCD**, the holographic model developed locally, to compute transport coefficients for the quark gluon plasma, most importantly the **bulk viscosity**. ([Kiritsis+coll.](#))
- The construction and study of simple **holographic models for the meson sector**, by implementing the characteristics of **tachyon condensation** from the Sen action to describe chiral symmetry breaking. The models are used in the quenched approximation ($N_c \rightarrow \infty$, $N_f = \text{fixed}$) and are remarkably similar to the real world both at zero and finite temperature. ([Iatrakis+Kiritsis+coll.](#))
- The natural continuation is to study models in the Veneziano limit ($N_c \rightarrow \infty$, $N_f \rightarrow \infty$, $x = \frac{N_f}{N_c} = \text{fixed}$). The whole phase diagram emerges with a conformal window, a QCD phase and a BKT/Mirasky conformal transition in between. The thermodynamics and spectra are rich and currently under study. ([Iatrakis+Jarvinnen+Kiritsis+coll.](#))
- The correct and improved description of **U-shaped brane configurations** (relevant for chiral symmetry breaking) using a **tachyon action** was proposed and tested in the hairpin branes in NS5 backgrounds. This sets up the proper framework for discussing the dynamics of chiral symmetry breaking in SS-like models. ([Niarchos](#)).
- The study of **energy loss by heavy quarks in a strongly coupled plasma**, by modeling the quarks by strings. The non-conformal characteristics of this energy loss were developed and surprises were found for the **Langevin evolution** of such heavy quarks at LHC conditions. Technical improvements turned out to be necessary in order to include these calculations into the Monte-Carlo's used in the ALICE experiment. ([Kiritsis+Mazzanti+coll.](#))
- The study of heavy quark motion in a magnetic field, gave a new perspective on energy loss, and a simple model of time-dependent horizons that can be studied further. ([Kiritsis+Pavlopoulos](#))

- The Study of **black-hole formation** during high energy collisions in non-conformal holographic theories. **Trapped surfaces** are used to obtain multiplicity estimates together with simplifications for the scale invariance from higher energies. The main tendencies in the energy dependence of the total multiplicity have been explored and a model has been proposed that agrees with EHC data and predicted correctly the data of the first LHC run. ([Kiritsis+Taliotis](#)). Similar computations have been made in theories with compact internal dimensions. ([Taliotis](#))
- The use of a holography-derived matrix model to describe multinucleon bound-states (nuclei), based on the SS model instantons and the investigation of the relevant physics. ([Morita+coll.](#))
- The study of **4D YM theory at large N compactified to two dimensions**. The phase diagram on anisotropic tori is matched between 2 and four dimensions both using QFT and holographic descriptions. Further the 5D SYM theory was studied, and the expected holographic confinement-deconfinement transition was debunked. A new proposal was made based on the Gregory-Laflamme instability for the transition which gives a new view for the restoration of chiral symmetry in the SS model. ([Morita+coll.](#))

RETURN

1C: AdS_4/CFT_3 and related issues

- The **F-maximization principle** was analyzed in a non-trivial model with $N=2$ supersymmetry in 3d and new non-trivial checks of the F-theorem were performed. A new criterion for **spontaneous supersymmetry breaking** in 3d was proposed using localization techniques and the three-sphere partition function. ([Niarchos+Morita](#)).
- Superconformal indices have been used to connect **Seiberg dualities** in 4 dimensions to analogous ones in 3d. ([Niarchos](#))
- A direct link between **holography and stochastic quantization** was proposed. ([Petkou+coll.](#)).
- A new class of three-dimensional vector models, (**the subdeterminant models**) was introduced whose effective potentials exhibit non-standard large- N behaviour. It was argued that the models are relevant for obtaining the effective actions of M2 and M5 branes. ([Petkou+coll.](#)).
- **Two dimensional large- N CFTs** were analyzed and several lessons were learned: they provide examples with a gravity description in AdS_3 , have an analogue of the reduction of the degrees of freedom at strong coupling and bulk states with multiplicity that is larger than the Cardy entropy. ([Kiritsis+Niarchos](#))

RETURN

2A: High-energy gravitational scattering

- Done by [Spirin+Tomaras+coll.](#)
- [Elastic scattering and gravitational radiation](#) in particle collisions at ultraplanckian energies have been studied.
- The purpose is to clarify the nature of gravity in the [ultraplanckian regime](#), especially in relation to the gravity "[classicalization](#)" [conjecture](#) and also to the black-hole production cross-section.
- For the elastic process a straightforward computation of classical scattering of two massive point particles in GR was carried out and reproduced in the ultra-relativistic regime the result obtained by other authors with different techniques, namely shock wave scattering ('t Hooft), or leading eikonal approximation in the context of quantum gravity (by Giudice, Rattazzi, Wells), or string theory (by Amati, Ciafaloni, Veneziano).
- The same pedestrian classical approach was used to compute scalar, vector, or gravitational radiation emitted in ultraplanckian collisions of particles interacting gravitationally. The preliminary result was that in collisions of massive particles and for impact parameter \gg Schwarzschild radius, for large enough collision energy [practically all available energy is emitted away](#).
- This result is currently under intensive scrutiny and extension in various directions.

RETURN

2B Quantum effects in cosmology

- A detailed study of the phenomenological consequences of the **quantum gravitational back-reaction to inflation** was done. This resulted in the construction of cosmological models with novel features, like the enhancement of very high frequency **primordial gravitational waves**.
([Tsamis+Romania+Woodard+coll.](#))
- A further study of the "Feynman rules" for the **graviton in de Sitter space-time** was also performed. This resulted in the construction of the graviton propagator for general invariant gauges. ([Tsamis+Woodard+coll.](#))
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RETURN

2C: Black holes and blackfolds

- Black brane solutions in higher dimensional theories of gravity play a key role in our general understanding of gravitational theories and gauge-gravity dualities. Niarchos has developed (together with Emparan, Harmark and Obers) a general effective field theory description of the long-wavelength dynamics of black branes known as the **blackfold approach**. This general hydrodynamic formalism of black holes has been extended recently to describe black brane intersections in generic (super)gravity theories and has been applied to a perturbative construction of new extremal and non-extremal black holes with exotic horizons, multiple charges and dipoles in string/M-theory. ([Niarchos+coll.](#))
- An innovative use of the **blackfold formalism** to the M2-M5 intersection in M-theory has produced a remarkable result: the first ever calculation of the central charge of the 2d CFT at the M2-M5 intersection. ([Niarchos+coll.](#)).

RETURN

3A: Hořava-Lifshitz gravity

- This class of gravity theories have broken part of the diff invariance, and a **Lifshitz scaling UV physics**. They were proposed as renormalizable alternatives to standard gravity. An analysis of the HL cosmology has been done, and it was pointed out that the UV scaling symmetry provides several ingredients that make inflation unnecessary. There is no horizon problem, the flatness problem is much milder, and there is a natural source of scale invariant cosmological perturbations. ([Kofinas+Kiritsis](#))
- **Spherically symmetric solutions** were analyzed in the original **HL gravity theory**, and the most general such solution was found. Although generical solutions have $1/r$ tails, several special ones are different, including the one with detailed balance. The modified geodesics in such solutions were formulated and shown that they have no horizons. ([Kofinas+Kiritsis](#))
- **Spherically symmetric solutions** were analyzed in the modified **HL gravity theory** proposed by Blas et al. This is a more complicated theory that is however in agreement with existing data. The solutions have generic $1/r$ tails except when the cosmological constant is present. These solutions are identical to those of “Einstein-Aether” theory. ([Kiritsis](#))

RETURN

3B: Lorentz violation in strongly coupled QFTs

- Study of the energy loss/dissipation in LV contexts due to Cerenkov radiation.

Employing recent results from holographic LV scaling geometries in condensed matter contexts a general study of energy loss is made and the possibilities have been classified. ([Kiritsis](#)).

RETURN

4: String Phenomenology

- The subject of **mass hierarchies in orientifold vacua** was addressed by studying the $U(1)$ symmetries associated with SM embeddings. These together with symmetry breaking and string instantons, classify the patterns of hierarchies. Several such patterns were found that agree with what we have in the SM. ([Kiritsis+coll.](#)).
- The Yukawa couplings in **orientifold realizing $SU(5)$ unified gauge symmetry** were analyzed generically. It was found that instanton effects that are necessary in order to generate top quark masses generate also unacceptable operators that mediate fast proton decay. ([Kiritsis+coll.](#)).

RETURN

Other

- Studies of [technicolor theories at finite temperature](#) and a calculation of the correlation between f_π and T_c for chiral symmetry restoration. ([Jarvinen+coll.](#)).
- Studying the phenomenological signatures of technicolor theories at LHC and linear colliders. ([Jarvinen+coll.](#)).
- Calculation of Hilbert series of N=1 sQCD with SU(N) gauge group. ([Jarvinen+coll.](#)).
- A proposal for holography in the Einstein framework with cosmological constant. ([Zhang+coll.](#)).
- An analysis of gauge theory holographic physics and confinement criteria in FRW cosmological geometries. ([Meyer+coll.](#))

RETURN

Detailed plan of the presentation

- Title page 1 minutes
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- Work-package 2:Personnel exchanges and twining 16 minutes
- Work-package 3:Organization of meetings 28 minutes
- Work-package 4:EXternal Advisory/Evaluation Committee 31 minutes
- The Physics Department 34 minutes
- The Crete Center for Theoretical Physics 40 minutes
- Networks, collaboration, Grants 42 minutes
- Education 44 minutes
- Outreach 46 minutes

- Overview of the Physics 47 minutes
- 1A: AdS/CMT 51 minutes
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