



### Science Meeting – Scientific Report

***Proposal Title:*** *Mathematica Summer School on Theoretical Physics - Selected Topics in Holography*

***Application Reference N°:*** 5293

#### 1) Summary

The *Mathematica Summer School on Theoretical Physics*, devoted to *Selected Topics in Holography*, took place in Porto from the 21st to the 26th of July of 2014. This was the 6<sup>th</sup> edition of this school, and counted with a total of 96 participants, including lecturers.

The school was divided in courses given by invited lecturers and in problem solving sessions. The mornings were devoted to the courses. The lecturers prepared before hand a number of problem sheets that were handed out to the students in the afternoon sessions. These sessions followed a hands-on approach to problem solving, with constant support by the school lecturers and also by some local advanced Ph.D students with considerable experience in the use of Mathematica.

The school covered a wide spectrum of topics in the subject of the gauge/gravity duality. Students were given a questionnaire at the end of the school, which showed an overall very positive assessment.

#### 2) Description of the scientific content of and discussions at the event

The scientific rationale behind the Mathematica School is to focus on a particular advanced research topic, and to teach students how to use Mathematica within that specific subject. The idea is to educate the students in this new powerful calculation tool, which clearly has been changing the way one does theoretical physics in the past years. The emphasis is still put on the physics, since students are solving advanced problems, reproducing non-trivial computations

proposed by the lectures (mostly already done in some form in published articles) under their supervision.

This edition of the school included lecture series on the following topics, mostly in the subject of gauge/gravity duality:

- *Mathematica* (Jason Harris - Wolfram Research)  
These were introductory lectures on the use of Mathematica. The idea was to level students, so one of these lectures actually opened the school. As time went by, these lectures became more advanced. Also, Jason Harris, a Mathematica developer at Wolfram with a Ph.D in Physics, was present throughout all the school, giving an invaluable contribution to help students on Mathematica related questions.
- *Higher spins and holography* (Simone Giombi - Princeton University)  
These lectures were devoted to the topic of higher spin theories in AdS spaces and their dual CFTs. Known cases of the duality involving higher spin theories were reviewed.
- *AdS black holes* (by Toby Wiseman - Imperial College London)  
The focus of these lectures was on setting the basics to solve numerically Einstein equations for stationary geometries using the Einstein-DeTurck method.
- *Quark-Gluon plasma* (Laurence Yaffe - University of Washington)  
Here the focus was on solving the time-dependent Einstein equations in asymptotically AdS spaces, setting up the basis to study dynamical problems that are dual to heavy ion collisions in QCD.
- *Integrability in AdS/CFT* (N. Gromov - King's College & P. Vieira - Perimeter Institute)  
This course was divided by two lecturers and it was an intermediate course between the research topic of integrability in AdS/CFT, and advanced Mathematica usage. The purpose was to give to the students a live view on how to use Mathematica (the lecturers were typing in the code in real time during their presentations, explaining the students what to do and how to think in a very explicit way).

All these lectures were complemented with Mathematica problem solving sessions, which took place during the afternoons of the school, and included exercises of low, medium and high difficulties, to accommodate for students of different levels of proficiency in the use of Mathematica.

Since some of the participants are already proficient users of Mathematica, there was also some space in the program for presentations by selected participants who volunteered to explain a particular usage of Mathematica encountered in their research activity.

### **3) Assessment of the results and impact of the event on the future directions of the field**

Already at its 6<sup>th</sup> edition, the Mathematica Summer School on Theoretical Physics is becoming an international reference in the field of theoretical physics (mostly in high energy physics). Many experienced researchers throughout the world recognize the importance of having their graduate students attending this school, to boost their computational expertise, in a demanding environment focused on a specific research subject, instead on only Mathematica code. This model has indeed proved to be very successful.

As an overall assessment we expect that students that attended the Mathematica School will become more powerful when facing hard computational problems in their research work. On a long term this will undoubtedly have a very positive impact in the field of theoretical physics. In particular, we believe that strong expertise in Mathematica considerably enlarge the set of problems one can solve analytically using symbolic manipulations that would be far too much time consuming and unpractical to do otherwise. To educate a generation of physicists in this front is bound to have an impact in the future of the field.

#### **Annex 4a: Programme of the meeting**

##### Day 1

- 9:00-9:15 Registration
- 9:15-10:30 Lecture: Mathematica
- 10:30-11:00 Coffee break
- 11:00-12:00 Lecture: Quark-Gluon Plasma
- 12:00-13:00 Lecture: Integrability in AdS/CFT
- 13:00-14:30 Lunch break
- 14:30-16:00 Problem solving session
- 16:00-16:30 Coffee break
- 16:30-19:00 Problem solving session

##### Day 2

- 9:15-10:30 Lecture: Higher spins and holography
- 10:30-11:00 Coffee break
- 11:00-12:00 Lecture: Quark-Gluon Plasma
- 12:00-13:00 Lecture: Integrability in AdS/CFT
- 13:00-14:30 Lunch break

14:30-16:00 Problem solving session  
16:00-16:30 Coffee break  
16:30-19:00 Problem solving session

### Day 3

9:15-10:30 Lecture: Quark-Gluon Plasma  
10:30-11:00 Coffee break  
11:00-12:00 Lecture: AdS Black Holes  
12:00-13:00 Lecture: Higher spins and holography  
13:00-14:30 Lunch break  
14:30-15:30 Lecture: Mathematica  
15:30-16:00 Problem solving session  
16:00-16:30 Coffee break  
16:30-19:00 Problem solving session  
20:00- School dinner

### Day 4

9:15-10:30 Lecture: AdS Black Holes  
10:30-11:00 Coffee break  
11:00-12:00 Lecture: Higher spins and holography  
12:00-13:00 Lecture: Integrability in AdS/CFT  
13:00-14:30 Lunch break  
14:30-16:00 Problem solving session  
16:00-16:30 Coffee break  
16:30-19:00 Problem solving session

### Day 5

9:15-10:30 Lecture: AdS Black Holes  
10:30-11:00 Coffee break  
11:00-12:00 Lecture: Integrability in AdS/CFT  
12:00-13:00 Lecture: Mathematica  
13:00-14:30 Lunch break  
14:30-16:00 Problem solving session  
16:00-16:30 Coffee break  
16:30-19:00 Problem solving session

Day 6

10:30-11:00 Morning coffee

11:00-12:00 Student presentations

12:00-13:00 Lecture: (Advanced) Mathematica

13:00 School ended

## Annex 4b: Full list of speakers and participants

### List of speakers

- Simone Giombi (Princeton University, US)
- Nikolay Gromov (Kings College, UK)
- Jason Harris (Wolfram Research, US)
- Pedro Vieira (Perimeter Institute, CAN)
- Toby Wiseman (Imperial College, UK)
- Laurence Yaffe (University of Washington, US)

### Full list of participants (96 in total)

Alex Arvanitakis	University of Cambridge, UK
Alex Turzillo	CALTECH, USA
Alexandre Serantes	Santiago de Compostela, Spain
Alfonso Bayona	CFP, Universidade do Porto
Alfredo Bonini	University of Bologna
Amadeo Jimenez	IFT-UAM/CSIC, Spain
Andrei Petrovskii	Institut de Physique Theorique, CEA/Saclay, France
Anson Wong	University of British Columbia, Canada
Antonio Pittelli	University of Surrey, UK
Aron Jansen	Utrecht University, The Netherlands
Aurelio Romero-Bermudez	University of Cambridge, UK
Behnoosh Khavari	IPM, Iran
Brandon DiNunno	University of Texas
Brenda Penante	Queen Mary University of London, UK
Charles Rabideau	University of British Columbia, Canada
Christian Marboe	Trinity College Dublin
Christiana Pantelidou	Imperial College London, UK
Damian Galante	Perimeter Institute for Theoretical Physics, Canada
Darren Smyth	University of British Columbia, Canada
Dimitrios Zoakos	CFP, Universidade do Porto
Edoardo Vescovi	Institute of Physics, Humboldt University Berlin, Germany
Edward Hughes	Queen Mary University of London, UK
Elias Kiritsis	CERN and UoC and APC, Greece

Elliot Banks	Imperial College London, UK
Emilia da Silva	IFT-UAM, Spain
Emilio Trevisani	CFP, Universidade do Porto
Felix Haehl	University of Durham, UK
Francisco Javier Martínez Lizana	University of Granada, Spain
Frank Coronado Idrogo	Perimeter Institute for Theoretical Physics, Canada
Genis Torrents	University of Barcelona, Spain
Georgios Linardopoulos	University of Athens & NCSR "Demokritos", Greece
Giancarlo Camilo da Silva	University of São Paulo, Brazil
Giulia Ferlito	Imperial College London, UK
Grigory Sizov	King`s College London
Ioannis Latrakis	Stony Brook University, USA
Istvan M. Szecsenyi	University of Durham, UK
James Gordon	NORDITA, Sweden
Jan Vincent Felix	King`s College London
Jarkko Järvelä	University of Helsinki, Finland
Jason Harris	Wolfram, US
Jesus Anibal Sierra Garcia	Santiago de Compostela, Spain
Jin-mann Wong	King`s College London
João Caetano	Perimeter Institute for Theoretical Physics, Canada
Jonathan Toledo	CFP, Universidade do Porto
József Konczer	WIGNER, Hungary
Julian Leiber	University Jena, Germany
Jun Bourdier	King`s College London
Ke Ye	CALTECH, USA
Laszlo Hollo	WIGNER, Hungary
Lauren Greenspan	CFP, Universidade do Porto
Laurence Yaffe	University of Washington, USA
Lucia Gomez Cordova	Perimeter Institute for Theoretical Physics, Canada
Luis Melgar	CSIC, Spain
Marc Scott	University of Southampton, UK
Marco Sanchioni	Niels Bohr Institute, Denmark
Maria Ioanna Christodoulou	University of Southampton, UK
Maria Irakleidou	Institute of Theoretical Physics, Vienna University of Technology
Martin Sprenger	DESY Theory Group, Germany
Massimiliano Rota	University of Durham, UK
Matteo Baggioli	University of Barcelona, Spain
Michael Cooke	King`s College London
Miguel Costa	CFP, Universidade do Porto
Mikhail Alfimov	ENS Ulm and CEA Saclay
Miquel Triana Iglesias	University of Barcelona, Spain
Mridula Damodaran	Purdue University, USA
Napat Poovuttikul	Leiden University, Netherlands
Nikolay Gromov	King`s College London
Olga Papadoulaki	Utrecht University, Netherlands

Panagiotis Betzios	Utrecht University, Netherlands
Pantelis Panopoulos	University of Athens, Greece
Pedro Gil Vieira	Perimeter Institute for Theoretical Physics, Canada
Peter Anderson	Purdue University, USA
Peter Jones	University of Southampton, UK
Petr Kravchuk	CALTECH, USA
Philipp Kleinert	University of Oxford, UK
Piermarco Fonda	SISSA, Italy
Raul Pereira	Uppsala University, Sweden
Robert Carcasses Quevedo	CFP, Universidade do Porto
Roman Yaresko	Helmholtz-Zentrum Dresden-Rossendorf, Germany
Saulius Valatka	King`s College London
Sebastian Moeckel	University Jena, Germany
Sheng-Lan Ko	University of Durham, UK
Simone Giombi	Princeton University, USA
Subhash Chandra Mahapatra	Indian Institute of Technology Kanpur, India
Timothy Raben	Brown University, USA
Toby Wiseman	Imperial College London, UK
Václav Tlapák	DESY Theory Group, Germany
Vasco Gonçalves	CFP, Universidade do Porto
Venkat Balasubramanian	University of Western Ontario, Canada
Witse Sybesma	Utrecht University, Netherlands
William Woodhead	University of Southampton, UK
Xinyi Chen	NORDITA, Sweden
Yago Bea Besada	Santiago de Compostela, Spain
Yunfeng Jiang	IPhT, CEA/Saclay, France
Yunseok Seo	Hanyang University, South Korea
Zachary Kenton	Queen Mary University of London, UK