

# Report on the 56<sup>th</sup> Cracow School of Theoretical Physics

## *A Panorama of Holography*

The 56<sup>th</sup> Cracow School of Theoretical Physics entitled *A Panorama of Holography* took place in Zakopane in the period 24<sup>th</sup> May- 1<sup>st</sup> June 2016. The aim of the school was to present a wide view on the contemporary research in the domain of holography (the AdS/CFT correspondence) starting from fundamental methods and constructions and going on to the investigation of very concrete phenomena in the physics of gauge theories.

There were six days of lectures, with 35 lectures given by the invited lecturers (see list below) and 12 seminars given by the participating students. The total number of participants was 64. Below I will discuss in more detail the scientific program of the school.

Jan de Boer from the University of Amsterdam gave a series of three lectures on *Entanglement and its Applications* which gave an introduction to the notion of quantum entanglement which recently arose as one of the key fundamental concepts for our understanding of the fundamentals of holography. Konstantin Zarembo from Nordita gave lectures on *Localization: from Exact Results to Holography* on a technique of supersymmetric localization which enables us to obtain exact results for some observables in supersymmetric gauge theories which provides a way of performing very precise quantitative tests of the AdS/CFT correspondence. Another series of lectures which introduced the audience to new theoretical tools, but this time in generic conformal field theories, were the lectures by Miguel Paulos from CERN on *Conformal Bootstrap*.

The next group of lectures concentrated on the theme of integrability which enables for solving exactly some specific string or gauge theories. Jan Plefka from the Humboldt University gave lectures on *Yangian Symmetry in  $N=4$  super Yang-Mills theory*, a hidden nonlocal symmetry in the maximally supersymmetric gauge theory which is the cornerstone of its integrability. Zoltan Bajnok, from the Wigner Institute in Budapest gave lectures on *How Integrability Works for AdS/CFT* which gave an introduction to integrability methods on the worldsheet string theory side, while Vladimir Kazakov from ENS Paris gave two lectures on *New Integrable 3D and 4D QFT's from Strongly Twisted  $N=4$  SYM* where he presented the latest results of his group on the construction of a very simple gauge theory which nevertheless still preserves integrability. The lectures by Jacob Bourjailly from the Niels Bohr Institute on *The Vernacular of the S-Matrix* gave a bridge to the last more applied group of lectures. In these lectures he introduced the most recent techniques of computing scattering amplitudes in gauge theories which partially arose from string theory techniques and properties of integrability but developed a completely novel language and set of methods.

The last group of lectures concentrated on holographical relations of gauge theories with gravity and their applications. Alejandra Castro from the University of Amsterdam gave the most theoretical lecture in this group entitled *Higher Spin Black Holes* which is related to the recently discovered novel version of holography which involves Vasiliev's higher spin gravity. The following two sets of lectures by Umut Gursoy from Utrecht University *AdS/QCD and the Quark-gluon*

*Plasma, and Holography, Thermalization and Heavy Ion Collisions* by Michał Heller from the Perimeter Institute, were concentrated on very concrete applications of holographic methods to the study of strongly interacting gauge theory quark-gluon plasma. The lectures of Karl Landsteiner from Madrid University *Anomalous Transport: Theory and Applications* gave an introduction to the manifestations of anomalies in the transport properties both of condensed matter systems and of quark-gluon plasma as well as their holographic description. The lectures of Adam Schwimmer from Weizmann Institute in Rehovot *Trace Anomalies and Constraints on Renormalization Group Flows* were also devoted to anomalies, but now aimed at describing the proof of the a-theorem on the renormalization group flow of the anomaly coefficient in four dimensions.

The lecturers present during the second half of the school (Zoltan Bajnok, Alejandra Castro, Michał Heller, Umut Gursoy oraz Konstantin Zarembo) also gave popular lectures for high school students who were present at a Kindergarten of Theoretical Physics organized by the Institute of Physics, Jagiellonian University in Kraków, for outstanding high school students interested in physics.

The financing by Holograv was extremely helpful and crucial for the organization of the school and covered the stays of lecturers and some PhD students, travel costs of three lecturers and some minor additional expenses. The website of the school is <http://th-www.if.uj.edu.pl/school/2016/>. Below I attach the list of lecturers and the list of student seminars during the school together with the links to the slides if applicable.

Best regards,

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## Lectures

1. **Zoltan Bajnok** (Budapest) *How Integrability Works for AdS/CFT* ([blackboard talk](#))
2. **Jan de Boer** (Amsterdam) *Entanglement and its Applications* ([blackboard talk](#))
3. **Jacob Bourjaily** (NBI, Copenhagen) *The Vernacular of the S-Matrix* ([1.pdf](#)) ([2.pdf](#)) ([3.pdf](#))
4. **Alejandra Castro** (Amsterdam) *Higher Spin Black Holes* ([blackboard talk](#))
5. **Umut Gursoy** (Utrecht) *AdS/QCD and the Quark-gluon Plasma* ([.pdf](#))
6. **Michał Heller** (Perimeter Institute) *Holography, Thermalization and Heavy Ion Collisions* ([1.pdf](#)) ([2.pdf](#)) ([3.pdf](#))
7. **Vladimir Kazakov** (Paris) *New Integrable 3D and 4D QFT's from Strongly Twisted N=4 SYM* ([.pdf](#))
8. **Karl Landsteiner** (UAM Madrid) *Anomalous Transport:*

- Theory and Applications* ([1.pdf](#)) ([2.pdf](#)) ([3.pdf](#))
9. **Miguel Paulos** (CERN) *Conformal Bootstrap* ([blackboard talk](#)) and ([.pdf](#))
  10. **Jan Plefka** (Berlin) *Yangian Symmetry in  $N=4$  super Yang-Mills theory* ([1.pdf](#)) ([2.pdf](#))
  11. **Adam Schwimmer** (Weizmann Institute) *Trace Anomalies and Constraints on Renormalization Group Flows* ([.pdf](#))
  12. **Konstantin Zarembo** (Nordita) *Localization: from Exact Results to Holography* ([blackboard talk](#))

## Seminars

1. **Xinyi Chen-Lin** (Nordita) *Holographic Wilson Loops in  $N = 2^*$  SYM Theory* ([.pdf](#))
2. **Brandon DiNunno** (University of Texas at Austin) *Thermodynamics and Bosonic Excitations of Holographic Metals* ([.pdf](#))
3. **Aleksander Garus** (ETH Zurich) *Classical Yangian Invariance of  $N=4$  SYM* ([.pdf](#))
4. **Oskar Henriksson** (University of Colorado at Boulder) *Holography from the Top Down* ([.pdf](#))
5. **Minkyoo Kim** (Wigner Research Centre for Physics, Budapest) *Three point correlators in  $N=4$  SYM*
6. **Philipp Kleinert** (University of Oxford) *Thermalisation of Wightman Two-Point Functions in AdS/CFT* ([.pdf](#))
7. **Julija Markeviciute** (University of Cambridge) *Hairy Black Holes in  $AdS_5 \times S^5$*  ([.pdf](#))
8. **Maciej Matuszewski** (Durham University) *AdS/CFT Model of Meson Decay* ([.pdf](#))
9. **Eugenio Megias** (Max Planck Institut für Physik, Munich) *Out-of-Equilibrium Energy Flow and Entanglement Entropy in AdS/CFT* ([.pdf](#))
10. **Benjamin Meiring** (University of Cape Town) *The Cusp of Anomalous Dimension in GPPZ* ([.pdf](#))
11. **Alvaro Veliz-Osorio** (Queen Mary University of London) *A story of Chaos and Purity* ([.pdf](#))
12. **Jack Williams** (University of Cambridge) *Twistor Methods for  $AdS_5$*  ([.pdf](#))

