12^{th} HGSFP Winter School

Obergurgl 2019

Final Report

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This document concludes the 12th HGSFP Winter School that took place at the University Center in Obergurgl from 16th to 20th of January 2019. In total, 52 graduate students from Heidelberg and 10 lecturers participated in the five-day event. The aim of the Winter School was to give students the opportunity to get insights into other research fields in Heidelberg apart from their own field. In the course of this, one of the focal points was the scientific exchange between the students themselves and students and lecturers in a friendly atmosphere. To this end, we organized a scientific programme consisting of 10 lectures given by speakers from Heidelberg and other universities and two poster sessions with elevator talks (see Appendix A).

Participant Selection

As expected, we received more applications for the school than spots were available. We therefore had to select participants from the pool of applicants, which we wanted to perform as fair as possible. We felt it was important to be both transparent about and accountable for our selection. For this reason, we imposed a selection algorithm, laid open the complete procedure (with anonymized data)[1], and explain what decisions went into the selection. In the following, we give an overview on how we selected the participants for the HGSFP winter school 2019.

Asking The Right Questions

Designing the application form was perhaps the most difficult task, and it is at this stage that conference organizers will already want to put serious thought into the goals of the workshop and the ideal mix of participants to achieve those goals. It should be obvious, but you will only be able to include categories in your selection that you actually ask for.

Pre-selection

Excluding speakers, we have 52 spots for the meeting. Our participant selection proceeded in two parts. In the first part, we rejected candidates outright who were either (1) duplicate entries or (2) candidates who had informed us that they would not be able to come. Two spots were reserved for the HGSFP representatives. Finally, we pre-selected the organizing committee, who needs to be present at the school. Thus, a total of 8 participants (6 organizers, 2 representatives) were pre-selected. We then anonymized our applicant pool by replacing names and other identifying information with a unique identifier.

For the remaining 52 - 8 = 44 slots, we used the software `entrofy` to optimize our participant set based on a set of well-defined criteria on which the organizers agreed. It's worth noting here that this discussion took place before performing the selection, which then depended entirely on the goals for the selection and was independent of the input data set.

[1] https://github.com/matiscke/HGSFPschoolParticipantSelection

Target Distributions

The targets define the fraction of participants in the final output set who share the same value of a property (e.g. 25% of participants should be affiliated with the HGSFP branch "Fundamental Interactions and Cosmology"). The target fractions must sum up to be smaller or equal to 1.0 for each category. If the target fractions sum to a value smaller than one, the algorithm will try to fill up categories to at least the given fractions, and will ignore that category for the rest of the optimization procedure. The resulting mix of participants in the final set for this category will thus be a combination of the input fractions and the distribution in the input sample, conditioned on the constraints set by the remaining categories. Below, we will go through each category one by one and lay out our reasoning for the categories chosen. The justification for our choices is an abbreviated version of a longer discussion the organizing committee had before starting the selection procedure. We should note at this point that there is no "correct" way to choose target fractions; the target fractions must necessarily always be a function of the objectives and goals of the workshop, as defined by the organizers.

Selection Goals

Broadly, the goals we defined for the HGSFP Winter School 2019 for participant selection are the following:

- enable every HGSFP student to attend one winter school during their PhD:
  - $\Rightarrow$ strongly favor applicants that have not attended a HGSFP winter school before
  - $\Rightarrow$ favor applicants that are longer into their PhD (since the clock is ticking...)
- Reflect the student numbers of the different HGSFP branches
- Increase the participation of underrepresented minorities (in our case this translates to an effort for gender equality)

HGSFP branch

For the branch attribute, we aim to reflect the distribution of the overall branch affiliation

Previous Winter School Attendance

Derived from our top requirement, the acceptance of applicants with previous attendance of a winter school should be an exception. We decided if we allow previous attendees at all based on the oversubscription of the school. The latter was not very high, we therefore decided to accept applicants with previous attendence only via the waiting list. We enforce this criterion further below and do not solve for this parameter.

Gender Identity

Any social engineering involving gender is necessarily subject to scrutiny. Our choices here reflect our beliefs about what we would like the Winter School to be: We recognize that underrepresented minorities are particularly underrepresented in physics, which is reflected in the number of non-male PhD students. We also recognize studies that show that diverse groups outperform groups lacking diversity among several axes. Representation is important: we believe that minority participants might feel more comfortable participating if they do not feel singled out based on their gender.

Realizing that an equal representation of genders cannot be realized given the input set, we choose to set a goal fraction of female participants slightly higher than the corresponding share in the HGSFP and allow a sufficient margin for the option "Don't identify with either".

PhD Duration
We aimed to give senior PhD students that have not participated in a Winter School before an advantage in the selection, since they have less or no opportunities to re-apply next year.

Aside from the organizers and representatives, the entire procedure was performed entirely without names and based only on the candidates' responses and the complex optimization of the participant selection with respect to our goals. After the selection, all applicants were informed about the outcome and applicants in the 'accepted' list were asked to confirm their attendance within a specified period. Not all participants accepted our invitation on the first round. Free spots were filled with applicants from the waiting list on a first-come, first-served basis with regard to our notification emails.

More detailed information about our selection procedure and an interactive Jupyter notebook that includes the original code can be found on
https://github.com/matiscke/HGSFPschoolParticipantSelection.

Lectures

We selected the lecturers based on a few key ideas: First, we tried to give the participants a glimpse of the wide range of different research areas within the HGSFP by selecting lecturers from very different research backgrounds both in experimental and theoretical physics. Furthermore, we asked lecturers at different stages of their academic career, from post-doctoral researcher to senior professor, to join the winter school, in order to encourage discussions between participants and lecturers on career choices in academia. Finally, we asked that all lecturers actively participate in the winter school in excess to their own lectures, in particular to allow for discussions with the participants in a relaxed atmosphere between lectures. Each lecturer gave two lectures of 90 minutes each, with three lectures taking place in parallel such that the participants were able to choose a schedule of lectures

according to their own interests. All lectures were structured in a way that also participants from different research fields could join. This opportunity to get a broader overview of the research activities within the HGSFP was embraced by the students. The combination of a high quality of lectures with a mixed, but interested audience lead to many discussions and exchanges of ideas during and also after the lectures. In addition to the regular schedule of lectures there was a special lecture for all participants on the topic of avalanche research. The special lecture was accompanied by an excursion the following day, where the participants were able to gain some insight into the practical aspects of avalanche research and risk assessment.

Poster Sessions

In addition to the lectures, the participants were asked to present their own research in form of a poster. There were two poster sessions on two of the evenings. We adopted the idea of previous years to start off the poster sessions by one minute-long 'elevator talks'. Here, all students presenting their research in the given poster session had the opportunity to introduce themselves and the topic of their poster within one minute. This helped the participants to get an overview of potentially interesting posters. The poster sessions were well received by the students which expressed itself in particular in the lively discussions during the poster sessions and in particular also afterwards.

Venue

The conference center of the university of Innsbruck was a perfect choice for the school. With all the participants and lecturers staying in the same place, the possibility to talk to other participants and lecturers was greatly enhanced. There were different rooms for all possible needs available, ranging from big lecture halls for the special lecture and the poster sessions, to smaller lecture halls, rooms for concentrated working as well as lounge areas for more relaxed discussions. A wide range of (sports) activities was available in the direct vicinity of the conference center. The staff of the conference center were very helpful in all situations, making the stay a very pleasant experience.

Travel

Similar as in previous years, the travel was done by bus over night with two drivers, which allowed them to drive without the need for stops or a hotel room in Obergurgl, as they could directly drive the way back. This allowed us to be in Obergurgl in time for breakfast. While it seemed exhausting for some people, as they arrival day did not have a fixed schedule and could be spent relaxing in the hotel, overall the participants where happy with this itinerary. Traveling back was done on the late afternoon, giving everyone the time to enjoy the last afternoon while arriving in Heidelberg just before 11

pm. Following the general mood, a similar itinerary schedule is recommended for the future.

Social Event

As a yearly tradition, the first evening of the Winter School was devoted to the social event — Eisstockschiessen. The event served well for people to get to know each other in a relaxed and fun environment. The scope of the event seemed to be appreciated with everyone joining. The last day was concluded with a big group going sledding which approximated a second social event, with less organizing and no funding, but being appreciated just as well.

Science Quiz

This year we organized a Science Quiz as an additional social event. Because this event was not in the program before the winter school, we regarded it as an additional, not mandatory event. Still, all the students and speaker participated enthusiastically. The participants formed teams and answered question from diverse topics ranging from fun facts about science to recent Nobel prizes. According to the survey and the atmosphere during the event the science quiz was a definitive success. The quiz itself did not cause any additional costs in the budget, because the rooms were booked for us because of the lectures and the prizes were merchandising articles from research projects at the Heidelberg University.

Lecture Abstracts

Building Planets - A Journey along 40 Orders of Magnitude

Til Brinstiel, Ludwig-Maximilians-Universität München

Building planets is a dirty business. First of all, planets are made out of the dirt we call interstellar dust. Secondly, the physics involved is not "clean" in a sense that neither the processes involved, nor the initial conditions are known. Solid state physics, radiation transport, gas phase and surface chemistry, magnetic fields and hydrodynamic instabilities at high Reynolds numbers are just some of the aspects that are certainly involved in growing the sub-micrometer sized interstellar dust by 40 orders of magnitude in mass to a full-fledged planet. Given this complexity and dynamic range, it is perhaps not surprising, that the formation processes of planets are still poorly understood, even though thousands of planets beyond our solar system are known today.

Some of the biggest mysteries of planet formation lie in the early stages: growing the asteroid-sized building blocks of planets. Recent years have seen a revolution in observing capabilities at various wavelength ranges delivering data of unprecedented detail and sensitivity. They have partially confirmed our theoretical expectations, partially surprised us. In this lecture, I will discuss some of the basic concepts and the problems we are facing from the theoretical side. I will outline how they might be overcome and will show how recent observational break-throughs revoluzionize this exciting field, bringing us closer to solving the puzzle of planet formation.

Galaxy Formation and Cosmology

Tobias Buck, Max-Planck-Institut for Astronomy (MPIA), Heidelberg

In these two lectures I will give a broad overview over the field of galaxy formation and evolution and the cosmological standard model. Cosmology governs the evolution of the spacetime of our Universe. Thus, I will first discuss the reasoning and implications of the cosmological model and highlight our understanding about nucleosynthesis and structure formation within this model. I will then move to describe the collection of observational facts about the galaxy population of our Universe in order to discuss the physical principles needed to explain these observations. Finally, I will briefly summarise current efforts and models in numerical galaxy formation to test physical mechanisms involved in the formation of galaxies.

Strongly Coupled Systems and the Applied Physics of Black Holes

Carlo Ewerz, Institute for Theoretical Physics, Heidelberg University

One of the most surprising findings of string theory is that quantum field theories and higher-dimensional gravity are closely connected, and can in fact be different descriptions of the same fundamental laws. The corresponding holographic dualities improve our understanding of fundamental theories of Nature and have many applications. In particular, they offer new and revolutionary insights into the behavior of strongly coupled quantum systems by connecting them to the physics of black holes. This has helped to discover universal behavior in many strongly coupled systems.

In the first part of the lecture, I will give a basic introduction to the principle of holographic duality. In the second part, I will present some examples and applications including the description of heavy quarks in a quark-gluon plasma and turbulence in a superfluid.

The lecture will start from basic (mostly undergraduate level) physics and does not require any expert knowledge of string theory etc.

Prospects and challenges of quantum computing

Martin Gärttner, Kirchhoff-Institute for Physics, Heidelberg University

"The first fusion reactor will be producing energy within 30 years from now." This statement seems to be true independent of when it is made. Similarly, the Wikipedia page on quantum computing has been stating for quite a while now "the development of actual quantum computers is still in its infancy". Will this statement ever be removed? The massive investments into quantum technologies that have been made by governments, companies, and military agencies especially over the last decade seem to suggest that the breakthrough is now within reach. In this lecture I will review some of the history of quantum computing and establish the basic language of quantum information consisting of quantum circuits built from unitary "quantum gates". Armed with this toolbox we will explore a simple quantum algorithm, the Deutsch-Jozsa algorithm, which illustrates how quantum superposition makes quantum computers superior to their classical ancestors. The last part of the lecture is dedicated to challenges for quantum computing like unavoidable sources of decoherence and how to use quantum error correction to mitigate this problem.

Unlocking Changes in Ocean Dynamics

Freya Hemsing, Institute for Environmental Physics, Heidelberg

Our ability to resolve current and past variability of the Earth's climate relies on our understanding of the circulation patterns and geochemical processes in the ocean. Interacting with the atmosphere, cryosphere and biosphere, the ocean occupies a key role in the global climate. The present oceanic system is measured directly in the scope of global scientific programs such as ARGO or GEOTRACES and simulated in computational models. Oceanic processes predominantly occur on time scales from a few decades to thousands of years. Therefore, to reliably constrain models for present and past oceanic changes, a look further back in the past, using geological records, is needed. Over the past decades the development of proxy-archive systems that record variations in oceanic conditions has been a key effort in paleoceanography. The most widely used archive is marine sediment, from which deep and surface ocean properties can be reconstructed. To detect changes in the thermocline (70 – 1000 m) which buffers and links the well mixed warm surface with the slow and cold deep water masses, the aragonite skeletons of cold-water corals are a suitable archive.

This lecture aims to provide a general overview of what is currently known about ocean dynamics and geochemical processes and how this knowledge was gained. A particular focus will be on the importance to understand the oceans' role in Earth's climate. In the second part, the benefits of paleoceanographic investigations will be outlined in form of a few example studies using both sediment and cold-water corals that yield insight into ocean properties and dynamics during the Last Glacial period.

Josephson junction based superconducting electronics

Sebastian Kempf, Kirchhoff-Institute for Physics, Heidelberg University

Advances in science, health care or other areas of everyday life are often accompanied by progress in physical instrumentation. The development of ultra-sensitive detectors and sensors is therefore of great importance and will not only influence our understanding of nature but also future examination methods in medical care or search strategies for natural resources. Josephson junction based superconducting electronics devices play an important role for these developments as they are among the most sensitive measurement instruments presently existing that enable fascinating investigations of tiniest signals. Josephson junction based interferometers and amplifiers, for example, are very well suited for measuring variations of tiny magnetic fields or any other physical quantities that can be naturally converted into magnetic flux. They are based on the Josephson effects as well as magnetic flux conservation and are used not only for measuring biogmagnetic signals as induced for instance by the electrical currents within the human brain but also to read out cryogenic particle detectors, to explore mineral deposits within geoscience or for magnetic sensing at nanoscale level. In this lecture, I will give an introduction into the fascinating field of Josephson junction based superconducting electronics, discuss different kinds of devices such as the well-known superconducting quantum interference device and highlight several applications for which superconducting electronics devices turn out to be a key technology.

High-Precision Tests of Quantum Electrodynamics - The g-Factor -

Florian Köhler-Langes, Max-Planck-Institut für Astronomie, Heidelberg

As the archetypal and best understood quantum field theory, quantum electrodynamics (QED) takes a prominent role in the highly successful Standard Model (SM) of physics. However, phenomena like dark matter and dark energy, which so far cannot be explained by the SM, challenge the model in a particular way. High-precision tests of QED might give a hint of physics beyond the SM. Furthermore, they lead to improved determinations of fundamental constants such as the electron mass or the fine-structure constant. In this lecture, we will introduce some high-precision tests of QED. A special focus will be set on measurements (and predictions) of the g-factor of the free electron, the free muon and the bound electron. In this context, a comprehensive introduction to state-of-the-art high-precision Penning-trap physics is given.

Hot QCD Matter Produced in Ultra-Relativistic Heavy-Ion Collisions

Silvia Masciocchi, GSI Darmstadt and Physikalisches Institut, Heidelberg University

TBA

Radiation Biology: Physics at the Forefront of Cancer Therapy

Joao Seco, German Cancer Research Center, Heidelberg

Medical physics (also called biomedical physics, medical biophysics or applied physics in medicine) is, generally speaking, the application of physics concepts, theories and methods to medicine or healthcare. There are 4 main areas of medical physics specialty 1) radiation therapeutic physics, 2) medical imaging physics, 3) nuclear medicine physics and 4) health physics, which cover more than 90% of all medical physics activities. Radiation therapeutic physicists work primarily in radiation oncology hospital departments, which specialize in cancer care. Radiation therapy (RT) is the most common treatment for cancer, being used in approximately 70% of all cancers either alone or combined with surgery or chemotherapy. It uses high-energy particles or waves, such as x-rays, gamma rays, electron beams, protons, carbon ions, to "kill" or "damage" cancer cells.
The first talk will give an overview of the physics behind radiation therapy. Starting from the first treatment of cancer done very early after the discovery of X-rays in 1895, to the technological developments in particle accelerators that permit modern day treatments with radiation and finally describing the impact of imaging, such as computed tomography (CT) and magnetic resonance imaging (MRI), in daily radiation therapy.
The second talk will provide an overview of the biological effects of radiation, starting from the very small cellular level leading to the very large patient response. A brief introduction to cellular biology and radiation chemistry is given to allow a better understanding of how radiation effects occur. The talk will focus on explaining how radiation can damage cellular DNA under different environment and cellular conditions such as varying 1) oxygen levels, 2) dose rate of radiation delivery, 3) radiation particle type, 4) cell cycle, 5) cell death mechanism, etc. Radiation biology is at the heart of understanding the molecular mechanism of how radiation damages cells, allowing us to better treat cancer while minimizing side-effects.

Special Invitation Lecture:

From snow to avalanches – a journey through scales and phase transitions

Achille Capelli, WSL Institute for Snow and Avalanche Research SLF

Snow on earth occurs in extraordinary variety of forms. It starts in the clouds with a phase transition from vapor to ice. As soon as the snowflakes reach the ground they sinter and form a continuous material constituted of an ice skeleton and air filling the pores. Subjected to the different weather conditions, the snow is transformed into different forms with various mechanical properties. This variability of mechanical properties of the snow cover allows the formation of avalanches. A dry-snow slab avalanche is released if a crack forms and propagates in a brittle weak layer below a cohesive slab. The initial crack is caused by a sudden surface load in the case of artificially triggered avalanches by e.g. a skier or an explosion. On the other hand, in the case of natural release the processes leading to initial crack formation are not fully understood. It is commonly assumed that a gradual damage process at the micro-scale leads to damage localization and the formation of the initial crack. This process can be seen as a phase transition. Moreover, the failure behavior of snow depends strongly on the imposed loading rate. Snow is brittle for fast loading and deforms plastically for slow loading. We will show how the acoustic emissions (AE) produced by microscopic cracking can be used to shed light on the damage process preceding failure and the mechanisms controlling the loading rate dependency. Moreover with a fiber bundle model (FBM) snow failure and the concurrent AE can be simulated. The FBM included two healing mechanisms that oppose the damage process: (a) sintering or regenerating broken fibers with time dependent probability, and (b) viscous deformation with resulting time dependent relaxation of load inhomogeneities. We show how the two healing mechanisms change the behavior of snow hindering the prediction of failure.

Final Remarks

In summary, the winter school was a great success. We are confident that the goals of the school were achieved, and the very positive feedback of students and lecturers strengthens this impression. The organizers are very thankful for the great organizational and financial support of the HGSFP for this event and we hope that the tradition of the winter school will be carried on in the future.

Abstract

Time	Wednesday 16.01.	Thursday 17.01.	Friday 18.01.	Saturday 19.01.	Sunday 20.01.
07:30	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast
08:30 - 10:15	Arrival in Obergurgl	**Strongly Coupled Systems and the Applied Physics of Black Holes** C. Ewerz	**Building Planets - A Journey along 40 Orders of Magnitude** T. Birnstiel	**Strongly Coupled Systems and the Applied Physics of Black Holes** C. Ewerz	**Radiation Biology: Physics at the Forefront of Cancer Therapy** J. Seco
		High-Precision Tests of Quantum Electrodynamics - The g-Factor F. Köhler-Langes	**Unlocking Changes in Ocean Dynamics** F. Hemsing	**High-Precision Tests of Quantum Electrodynamics - The g-Factor** F. Köhler-Langes	**Prospects and Challenges of Quantum Computing** M. Gärttner
		Josephson Junction Based Superconducting Electronics S. Kempf	**Hot QCD Matter Produced in Ultra-Relativistic Heavy-Ion Collisions** S. Masciocchi	**Josephson Junction Based Superconducting Electronics** S. Kempf	**Galaxy Formation and Cosmology** T. Buck
10:30 - 15:30		Break	Break	Break	Break
17:00 - 18:45		**Building Planets - A Journey along 40 Orders of Magnitude** T. Birnstiel	**From Snow to Avalanches – A Journey through Scales and Phase Transitions** A. Capelli	**Radiation Biology: Physics at the Forefront of Cancer Therapy** J. Seco	Departure
		Unlocking Changes in Ocean Dynamics F. Hemsing		**Prospects and Challenges of Quantum Computing** M. Gärttner	
	Dinner at 18:00	**Hot QCD Matter Produced in Ultra-Relativistic Heavy-Ion Collisions** S. Masciocchi		**Galaxy Formation and Cosmology** T. Buck	
19:00		Dinner	Dinner	Dinner	
20:00 - open End	Social Event	Elevator Talks	Elevator Talks	Introduction to the HGSFP	
		Poster Session	Poster Session		