SigmaCamp Lectures

August 12-19, 2018

Lecture dates are subject to change

Contents

Sunday: Opening lecture

Science in 2018
by *Michael Bershadsky*

I give a brief review of exciting recent discoveries: from gravitational waves to artificial intelligence, from gene therapy to the discovery of potentially habitable worlds...

About the lecturer: *Michael Bershadsky got his PhD in physics from Princeton University in 1990. Immediately after this he came to Harvard University, where he was on the faculty until 2000. In 2000 he resigned from Harvard University and joined a private company.*

Monday

Chemistry of DNA Synthesis, And Why we Are Not Immortal
by *Mark Lukin*

DNA synthesis is a core reaction that makes life possible. During this lecture, we will experimentally demonstrate what is the driving force of this reaction and learn why DNA copying is so accurate. We will also learn about auxiliary enzymes that help DNA synthesis to start, and will see how all of that makes us mortal.

About the lecturer: *Mark Lukin is a Research Assistant Professor in Pharmacology Department of Stony Brook University, NY. The focus of Mark Lukin's scientific interest are nucleic acids (DNA and RNA) - the molecules responsible for storage and transfer of hereditary information in living organisms. How does DNA get copied? What happens when DNA molecules breaks? To answer these, as well as many other questions, Mark needs to prepare artificial (modified) nucleic acids and their building blocks, the crazy compounds that normally do not exist in nature. The only way obtain them is to do a chemical synthesis, the thing Mark likes the most. Besides that, Mark loves music, history, Greek philosophy, and science fiction. When he was young, he loved to do simple but spectacular chemical experiments. Recently, he realized he still loves to do that. He plans to do some of those experiments in SigmaCamp 2018 with our campers.*

Choreography in Physics
by *Alexander Turbiner*

Choreography is when n particles move on the same trajectory "chasing" each other. This phenomenon was discovered recently by accident by C. Moore (1993) in Newtonian gravity and is the subject of intense studies. It is related to the following question: take closed curve, can it serve as trajectory for 3,4, etc. particles?

About the lecturer: *Alexander Turbiner is a Professor and Leading researcher at Nuclear Science Institute, National University of Mexico. He got his PhD and DSc from Institute for Theoretical and Experimental Physics in Moscow. His research lies at the intersection of theoretical physics and mathematics. His expertise is non-perturbative, (Lie)-algebraic, variational methods in quantum mechanics and quantum field theory. He is mostly known for introducing the notion of "quasi-exact-solvability" when some but all properties of a physics system are known exactly. He has dedicated a lot of efforts exploring physics in a strong magnetic field.*

On the Interpretation of Quantum Mechanics
by *Helmut Strey*

In my lecture I will review the basic principles of quantum mechanics and review the history of its interpretation. In particular, I will point out consequences of the probabilistic predictions of quantum mechanics and how these can be reconciled with a mechanistic worldview. Towards the end I will introduce a Bayesian interpretation of quantum mechanics that may resolve some of the problems with a frequentist interpretation.

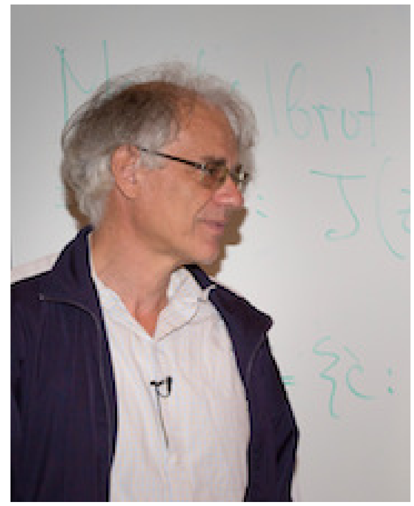
About the lecturer: *Helmut Strey is the Director of the Laboratory for Micro- and Nanotechnologies (www.streylab.com) and Associate Professor in the Biomedical Engineering Department at Stony Brook University. Helmut Strey is a Biophysicist who is interested in developing micro- and nanotechnologies for applications in basic and applied research. Specifically, his lab is working on 1) microfluidic techniques for single-cell cancer genomics, 2) study of DNA dynamics in confined geometries to understand how gene regulation works, 3) developing wireless biosensors for home sleep studies. Helmut received the Dillon medal for research in Polymer Physics from the American Physical Society in 2003. He recently converted to Bayesianism and is passionate about making things, Soccer and Table Tennis.*

Cryptography in the Modern World — Classical And Quantum
by ***Julia Kempe***

The desire to keep messages secret goes back several millennia. Apparently, already Julius Caesar used a substitution cipher (now called the Caesar cipher) for sensitive private and military correspondence. The cipher involves shifting all of the letters in a message in one direction a secret number of times, wrapping around if necessary. This appears to have worked well for Caesar, but could he have done better? The cipher itself is quite trivially breakable. We will review some cryptographic ideas and outline current state of the art encryption. An interesting twist comes from the advent of quantum computing: many current crypto-systems can be broken once a quantum computer is built. However, quantum information opens new possibilities as well. We will give an idea of quantum key distribution and post-quantum cryptography.

About the lecturer: *Julia Kempe completed her PhD in Mathematics at UC Berkeley, and has been a researcher in France and a Professor at Tel Aviv University, working in quantum computation and information. She left academia in 2011 to work for a private company, but is now returning to New York University, where she is the Incoming Director of the Center for Data Science and Professor of Computer Science and Mathematics, starting this Fall.*

How to Control Chaos?
by *Misha Lyubich*



Everything around us is changing in time according to certain rules. Some of these motions look quite simple and predictable with full confidence (e.g., periodic returns of Halley's comet to the Solar System), others are quite chaotic and unpredictable beyond very small intervals of time (e.g., the weather forcast on Long Island). A mathematical description of such phenomena is a subject of Dynamical Systems Theory.

After giving a general idea of a mathematical meaning of dynamical system, we will discuss several basic notions of the theory: fixed and periodic points, orbits, their stability and instability. "Chaos", related to instability of large number of orbits, is difficult to control, but mathematicians did not give up and found some way of doing it, at least in an average sense over long time intervals. We will try to explain what it means on some simple examples.

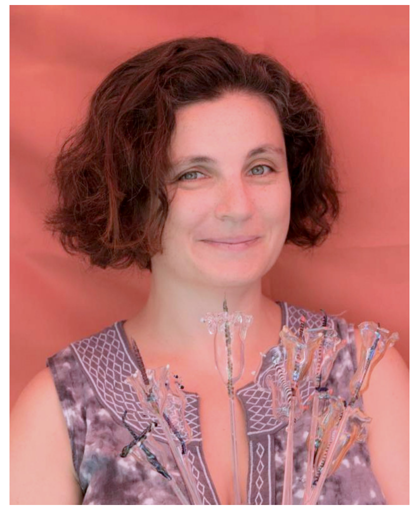
No preliminary knowledge is expected of the students.

About the lecturer: *Misha Lyubich is a Distinguished Professor of Mathematics and Director of the Institute for Math Science at the Stony Brook University. Misha has been working on dynamical systems given by simple formulas in low dimensions but exhibiting an interesting chaotic behavior and producing intricate fractal objects. It is concerned, in particular, with the real and complex quadratic family. Fractal objects like Julia sets and the Mandelbrot set naturally emerge in this context. He has dedicated a lot of effort exploring their universal self-similar structure encoded by a scary term (coming from physics) "renormalization".*

Tuesday

Action Adventure. Life in the World of Art
by *Vicka Bershadsky*

Art pieces live through as much action as in The Game of Thrones and as much mystery as in the DaVinci Code. They do not spend their hundred or thousand year lives passively on museum shelves, but participate in the business and politics, the loves and crimes of the people around them. We will explore some of the exciting histories of the lives of the inanimate.



About the lecturer: *Victoria has a degree in Economics and Art History. She worked with numerous cultural organizations and was involved in various history, art, and anthropology programs. Victoria still spends a lot of time on arts and history. At SigmaCamp Victoria wants to show a different angle of life by opening up the world beyond science.*

Geometry of Möbius Transformations
by *Sabya Mukherjee*

Möbius transformations are maps of the sphere that preserve angles and send circles to circles. They are made up of familiar maps like translations, rotations and dilations, and perhaps less familiar "inversions". Though they can be defined in this elementary geometric way, the best way of understanding them is by using complex numbers.

After a quick introduction to complex numbers, we will define the "Riemann sphere" via stereographic projection by adding a point at infinity to the complex plane. Then we will introduce Möbius transformations and discuss their basic geometric properties. As an illustration, we will show how to solve the classical Apollonian problem on constructing a circle tangent to three given ones.

About the lecturer: *Sabya is a Lecturer in Institute for Mathematical Sciences, Stony Brook University, NY. He received his PhD in Mathematics from Jacobs University Bremen, Germany in 2015. His main research interest is in dynamical systems, especially in the topological and fractal properties of parameter spaces of holomorphic dynamical systems. He has been a part of the organizing committees of various math summer schools in the past.*

Mysterious and Surprising Properties of Black Holes
by ***Zohar Komargodski***

Black holes are perhaps the most strange and fascinating objects known to exist in the universe. Our understanding of space and time is pushed to its limits by the extreme conditions found in these objects. We discuss classical aspects of Black Holes, emphasising concepts that are relevant for the recently observed Black Hole collisions. Then we describe some of their mind-bending quantum properties and discuss Hawkings mechanism of Black Hole evaporation, the associated Information Puzzle and its recent resolution. We outline some of the remaining open questions.

About the lecturer: *Zohar is a Professor at Simons Center for Geometry and Physics, Stony Brook University, NY. He studied at the Weizmann Institute in Israel, where he received his PhD in 2008. Later he joined the Institute for Advanced Study in Princeton. In 2011 Zohar returned to the Weizmann Institute, and in 2017 joined the Simons Center for Geometry and Physics. His research is on Quantum Field Theory, which has applications on a wide variety of fields in physics, including Particle Physics and Condensed Matter Physics.*

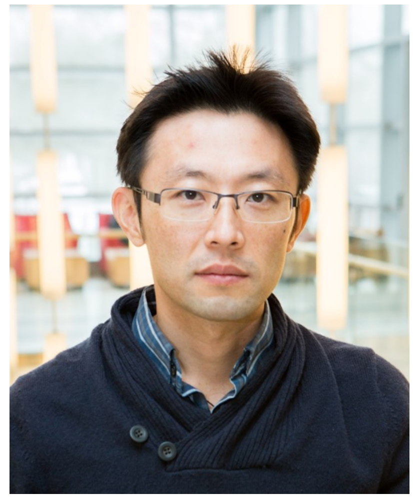
Chernobyl Catastrophe: How a Nightmare Happened
by ***Igor Zaliznyak***

The Chernobyl accident, which happened on April 26, 1986 in a nuclear reactor in Chernobyl power plant in Ukraine (at that time part of the Soviet Union), is considered the most disastrous nuclear accident in history. Thousands of people had to be evacuated, and the area within 30 km radius of the reactor remains an uninhabited exclusion zone to this day.
In this lecture we will discuss how the reactor worked, what safety mechanisms it had — and what made the accident possible. We will also discuss whether an accident like this can happen in the future.

About the lecturer: *Dr. I. Zaliznyak is a physicist at Brookhaven National Laboratory, where he studies microscopic quantum properties of matter using neutron particles. Among others, these include exotic quantum states of electrons in metals, such as superconductivity, magnetism, and superfluidity in quantum liquids. Dr. Zaliznyak obtained his Ph. D. degree at the P. Kapitza Institute for Physical Problems, Moscow, in 1993. He also teaches math at SchoolNova.*

Wednesday

Bayesian Updating and Cognitive Control
by *Jaime Ide*



The Bayesian Brain hypothesis is a quite powerful and intuitive model of our thoughts and knowledge. According to this view, people assign probabilities to their beliefs (hypothesis) and update them when additional information is available, using the Bayes rule. However, there is still a huge debate on how, and whether, this broad theory is actually implemented in the brain. In this lecture, I will tackle a small piece of this puzzle by showing how a key prefrontal brain region involved in cognitive control responds to Bayesian expectations using functional MRI. Furthermore, I will describe how this modeling can provide clinically relevant information.
Prerequisites: Basic probability theory including conditional probabilities and Bayes rule. Basic knowledge of the brain organization.

About the lecturer: *Jaime Ide is a Mechatronic engineer that became Computational Neuroscientist and Data Scientist. He got his Ph.D. in Artificial Intelligence from the University of Sao Paulo, Brazil (2005), and received his training in MR imaging at the University of Pennsylvania (2007-2008) and Yale University (2008-2010). Currently he is Associate Research Scientist, Psychiatry Department, Yale University.*
Broadly, he is interested in the application of Bayesian methods, computational modeling, and machine learning in cognitive neuroscience, neuroimaging, decision-making, as well as in real-world predictive problems. He is passionate about robotics, chess, and table tennis.

Music, Stars and a Touch of Witchcraft: How Physics Was Born
by *Aleksei Tkachenko*

Physics as a science is surprisingly young: it was around for only three centuries. By the time Isaac Newton published his classical work "Mathematical Principles of Natural Philosophy" in 1687, the mankind had already built enormous structures, ships and machines, used guns in wars, and Europeans have colonized much of America. This was all done without understanding of the very basic laws on Nature! In my lecture I will discuss, why and how those laws were eventually discovered. It will be a mix of science, history and personal stories of those involved, some of them more appropriate for a tabloid magazine rather than a textbook. I will talk about a curious sequence of events that occurred almost exactly 400 years ago, that laid the foundation of Newtons Classical Mechanics.

About the lecturer: *Aleksei Tkachenko is a theoretical physicist at Brookhaven National Laboratory working on nanoscience and in the field called soft condensed matter. He studies problems that range from from living matter (DNA, proteins, membranes) to nanoparticles, plastics and even sand. He also teaches physics at School Nova. At SigmaCamp, Alexei is responsible for the tastiest of all the semilabs, called "Physics in the Kitchen".*

Space, Time and the Fourth Dimension
by *Robbert Dijkgraaf*

Albert Einstein told us that time should be seen as a fourth dimension. What does this exactly mean? How should you image higher dimensions? And how does it help us understand fundamental questions in physics like the Big Bang, black holes, and the behavior of elementary particles?

About the lecturer: *Robbert Dijkgraaf is a tenured professor at the University of Amsterdam and the director and Leon Levy professor at the Institute for Advanced Studies in Princeton, N.J. He obtained his Ph.D from the University of Ulbrecht in 1989 cum laude studying string theory. His research lies at the crux of mathematics and particle physics. He received the the Spinoza prize in 2003, the most prestigious scientific award in the Netherlands, for his contributions to science. In 2012 he was named a Knight of the Order of the Netherlands Lion. Robbert writes a monthly newspaper column in the NRC Handelsblad and regularly appears on television.*

Ocean Deoxygenation: Another Consequence of Climate Change
by ***Gordon Taylor***

Through geologic history, the worlds ocean has oscillated between normal and oxygen-depleted conditions no fewer than 17 times in response to climatic warming and cooling, and changes in sea level, circulation and biological productivity. The most severe oxygen depletions coincide with massive extinction events evident from the fossil record. In modern aquatic systems, oxygen-deficient water columns (ODWCs) commonly occur at depth in stratified lakes, seafloor depressions (basins), isolated seas, and nearshore coastal oceans, and can extend thousands of kilometers offshore as so-called oxygen minimum zones (OMZs). Oxygen depletion in water columns varies in intensity, depending on biological productivity and mixing of water layers. The imbalances producing oxygen depletion may be short-lived or seasonal or permanent. The geographic extent of waters experiencing low oxygen conditions is significant; affecting most coastal waters and permanent OMZs occupy about 10% of the open ocean volume. Since coastal waters serve as important nurseries for many fish species, oxygen depletion reduces suitable habitat for sensitive early life stages, elevates death rates, and presumably reduces reproductive success. Thus, oxygen depletion in critical locations can have unexpectedly large effects on biogeography and biological productivity. Oxygen-deficient water columns are becoming more extensive globally. They are also sites of intensive elemental cycling by specialized microorganisms. This lecture gives an overview of ocean deoxygenation, explores causes, temporal trends, their unique geochemical and microbiological features.

About the lecturer: *Gordon T. Taylor is a Professor in School of Marine and Atmospheric Sciences, Stony Brook University, NY. He earned his Ph.D. in Microbial Oceanography at the University of Southern California in 1983. He completed his postdoctoral training at the University of Hawaii, Honolulu and then joined their research faculty in 1985. In 1990, he joined the Stony Brook University faculty. His research efforts have mainly focused on microbial mediation of biogeochemical process (particularly carbon cycling), effects of climate change, trophic interactions among microorganisms (bacteria, protozoans, algae and viruses), and linking ecological function to specific microbial community members. His study sites have spanned shallow coastal waters to the deep sea and from the tropics to the Antarctic. His lab's toolkit includes molecular approaches (qPCR, DNA sequencing, FISH), stable isotope tracers, Raman microspectrometry, and atomic force microscopy.*

In Search of Language Universals
by ***Andrei Antonenko***

There are about 7,000 languages in the world. Is there any property that every language has? In this lecture we will take a look at language universals — statements which define what must (in all languages, X happens) or what is extremely likely (in most languages, X happens) occur in all world languages. We will also consider some correlations of form "In all (most) languages, if there is X, there is also Y," that you can safely bet on.

Apparently, languages are never random and number of such universals is pretty significant. They span all domains of human language: sound system, grammatical system, lexicon, meaning. We will look at examples from all of these domains and try to understand how such generalizations about human languages can be explained, by looking at theories proposing historical, biological, and other explanations of these universals.

About the lecturer: *Andrei Antonenko is a lecturer in Linguistics department of Stony Brook University, NY. He has received masters in Applied Mathematics and PhD in Theoretical Linguistics from Stony Brook University in 2012. His area of specialization is generative syntax, and he works on a variety of languages, including Slavic, Germanic, Austronesian, East Asian, Caucasian, and others.*

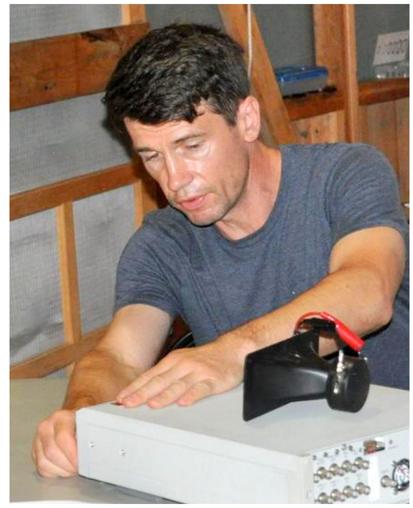
Thursday

Sun: Life as a Star
by *Inna Sus*

Extraordinary, and at the same time very ordinary, is the star closest to us our very own Sun. Such proximity, only 8 light minutes away, provides us an opportunity to test our ideas about how stars are born and how they work and die, as well as how they affect their surroundings. 2×10^{30} kg of Sun's pure plasma are gentle enough to nourish life and violent enough to destroy planets. With a temperature variation from 15 million degrees Kelvin in the center to almost 6000 Kelvin on the surface, this nuclear fusion powered machine is one of the wonders of the universe whose ordinary life is full of extraordinary events. We are going to talk about the evolution of Sun, its structure and sources of its power, as well as the impact it has on us. Even thought Sun was around for more than 4 billion years, only recent advantages in technology (such as constant satellite observations) allowed us to see it up close and get a deeper understanding of our own star.

About the lecturer: *Inna Sus was a visiting scientist at Los Alamos National Laboratory, where she worked on various projects related to computational materials. Currently, she is a scientific editor reviewing research papers in Physics and Astronomy.*

A Quest for Brighter Light
by *Boris Podobedov*



Accelerator-based light sources produce exceptionally intense beams of X- rays, ultra-violet and infrared light, making possible both basic and applied research in fields ranging from physics to biology to technology. Some of the more novel light sources cost upwards of $1Bn, and yet governments around the world keep investing this kind of money. Why are they doing it? What are these unique properties of light that these light sources provide, and why they are not achievable with your typical flashlight or even a powerful laser? This lecture will answer these questions as well as explain how accelerator-based light sources work.

About the lecturer: *Boris is a Physicist in Photon Sciences Directorate of Brookhaven National Laboratory, NY. He got his PhD from the Stanford University Department of Applied Physics. His expertise is to design, build and operate large particle accelerators. These are mostly used as research tools for high energy physics, or serve as light sources that provide powerful X-ray beams to the researches from many different fields of science.*

Benford's Law
by *Alexei Borodin*

If one looks at population numbers of all the towns in the United States then one sees that the leftmost digit of those numbers is "1" about 30% of the time and "9" less than 5% of the time. The same happens with electricity bills, length of rivers, and street addresses. This observation is known as Bendford's law.

In this lecture we will investigate this law and explain why it works. We will also discuss how it can be used, for example for detecting fraud in financial documents.

The lecture expects that the students are familiar with high school algebra and logarithms.

About the lecturer: *Alexei Borodin received his Ph.D. in mathematics from the University of Pennsylvania in 2001. He was a professor at Caltech in 2003-2010, and since 2010 he is a professor of mathematics at MIT. Alexei enjoys working on problems on the interface of algebra and probability.*

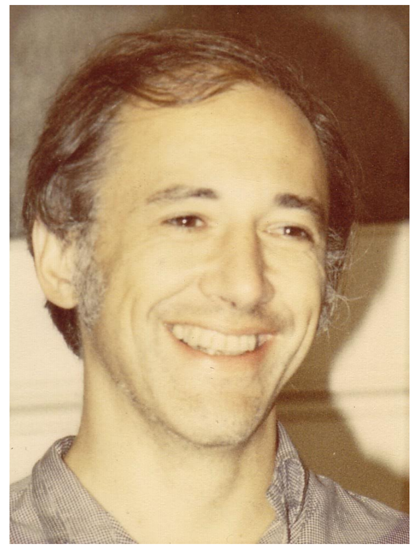
Fundamentals of Drug Discovery
by ***Dima Kozakov***

What is a drug? What is the drug's target? How does the drug works? What type of drugs can be there? How to discover drugs and their targets rationally? How long does it takes to discover and validate the drug? If you are interested — come to the lecture.

About the lecturer: *Dima is an Assistant Professor at Stony Brook University. Mathematician and Physicist by training, Dima likes to develop new approaches for prediction and design of molecular interactions using elegant concepts from theoretical physics and mathematics. He also enjoys mythology, traveling around the world, and alpine climbing.*

Friday

Galileo and the Second-Order Infinitesimal
by ***Richard Friedberg***



In the Second Day of the Dialogue on the Two Chief World Systems, Galileo argues that no matter how fast the earth were to revolve, objects would not be thrown off. Of course this is not so: the example of manmade satellites shows that loose objects would levitate if the earth were to complete a revolution in less than an hour and a half.

Galileo rests his argument on the fact that a second-order infinitesimal always becomes less than a first-order infinitesimal in the limit. But he overlooks that the quantity he thinks is first- order really is also second-order so that the comparison depends on the coefficients. On the one hand his mistake is a foolish one in the sense that he would have known better if he had been paying close attention. On the other hand the whole performance is astounding: the subject of first-order infinitesimals was known only to a few, and no one had done anything comparable with second-order.

I shall explain how the discussion relates to the objections against the Copernican system. Then I shall expand and elucidate the complicated diagram Galileo provides, and show what his mistake was. Finally I shall explain how he was seduced into his error by the distraction of trying to explain things in a way acceptable to Simplicio, his opponent in the dialogue.

About the lecturer: *I graduated from Harvard College in 1956. After some false starts I took a PhD in physics at Columbia. From 1968 to 2003 I taught physics at Barnard College and Columbia University. In the course of my teaching I had occasion to study in detail the early experiments of Galileo on the behavior of falling bodies. I've published over 100 peer-reviewed papers in math and physics. I'm trying to stay alive as a researcher and practising piano a lot.*

Unexpected Nobel: Quick Rise of Supramolecular Chemistry
by ***Eugene Pinkhassik***

A surprising discovery in an industrial laboratory resulted in an explosion of research on non-covalent interactions between molecules. This discovery gave rise to a new chemical discipline dubbed Supramolecular Chemistry, which creates and studies small objects such as molecular machines, molecular containers etc., each of which is made up of several molecules held together by a network of a large number of weak interactions. Was this discovery truly accidental? Our conversation will range from the role of serendipity in science to the development and maturity of a new research field. We will see how simple ideas influence thinking of scientists, impact related areas, and translate into practical applications.

About the lecturer: *Eugene Pinkhassik graduated from Kazan State University in Russia and obtained his PhD in Chemistry in the Institute of Chemical Technology in Prague, Czech Republic. After a visiting scientist stay in Parma, Italy and a postdoctoral fellowship at the University of Colorado, Boulder, he began an independent faculty career. He is currently an Associate Professor at the University of Connecticut. His research interests focus on making nanomaterials and nanodevices with new and superior properties to address current problems in energy-related technologies, medical imaging and treatment, and environmental sensing.*

The Dawn of Quantum Computing
by ***Sergei Dubovsky***

For decades quantum computing was a dream and a nice theoretical toy. Currently several prototype machines are operating and you even can run quantum programs online at IBM Q Experience website. Optimistically, quantum computers will beat classical ones on certain tasks within a few years. I will review the underlying principles of quantum computing and recent developments.

About the lecturer: *Sergei Dubovsky is an Associate Professor of Physics, Center for Cosmology and Particle Physics, Physics Department, New York University. He received his PhD in physics in 2001 from INR (Moscow, Russia). He served as a junior research fellow at CERN, Harvard and Stanford before joining the Center for Cosmology and Particle Physics at NYU in 2010. Sergei works on the interface of string theory, particle physics, and cosmology*

How Proteins Fold and Communicate?
by *Ora Schueler-Furman*

In my lecture I will introduce the camp participants to the world of proteins. Proteins are the workhorse of the cell: they are responsible for the proper functioning and regulation within and between cells. How do they achieve this? For this, we need to understand how these units are built, and how they communicate with each other.
I will first provide a brief introduction into the world of proteins: what are the parameters that determine how they will fold into a functional unit? How do we model them? In particular, I will describe how these models have been improved using web resources (computers as well as people). Then I will describe how we study protein communication using tools developed for the study of social networks on the web. The study of proteins at the level of individuals, as well as social networks provides interesting insights on basic principles of organization and complexity that make life possible.

About the lecturer: *Ora Schueler-Furman is a Professor in the Department of Microbiology and Molecular Genetics at Hebrew University of Jerusalem, Israel.*
She studied at the Hebrew University for her BSc, Msc and PhD. She then joined lab of David Baker at the University of Washington for Postdoctoral studies. Since 2005 she has been a Faculty member of the School of Medicine at the Hebrew University. Oras research focuses on the computational and experimental characterization of protein interaction and their functional biological role.
We are interested in understanding the basic biophysical principles that govern biological complexity. In particular, we focus on an important class of interactions that is mediated by short, linear sequences - peptides. These interactions are often transient in character, and therefore challenging to study, both by experiment as well as by computation. Our group has developed leading approaches for the accurate modeling of the structure of peptide-protein interactions, and used these approaches for the structure-based identification of substrates of peptide binding proteins and peptide modifying enzymes. Our findings reveal new layers of complexity in biological regulation.

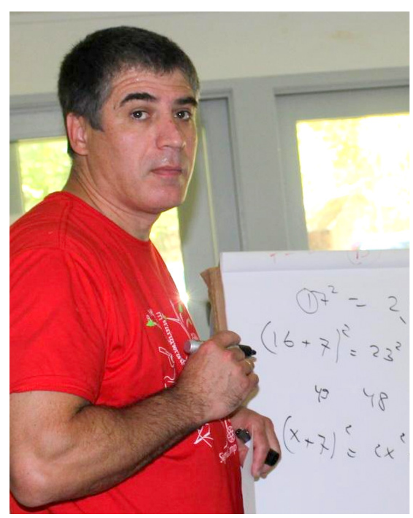
Saturday

Allen Brain Science
by *Ioulia Rouzina*

In 2003 the co-founder of the Microsoft and great philanthropist Paul Allen started the Allen Brain Institute in Seattle. This Institute now leads the global effort on understanding how the human brain functions. In this lecture I'll try to describe and discuss various cutting edge methods that this Institute uses to visualize, functionally characterize, map and model the brain applying the "big data" approaches.

About the lecturer: *Ioulia is a Research Assistant Professor at Ohio State University. She graduated from St. Petersburg Physics Technical University with PhD in Theoretical Condensed Matter Physics. She later moved to Minnesota, where she joined the Biophysics lab working on understanding how various proteins interact with DNA and condense it in the nucleus, and how individual DNA molecule can unwind its two strands under the mechanical tension. Ioulia is now a research assistant professor at Ohio State University in Columbus working on molecular biology of HIV and other retroviruses. We are now trying to understand how HIV selects its RNA genome for packaging, and how the HIV capsid falls apart after infecting the cell.*

How to Bend Light? Applications of Fermats Principle
by *Sasha Abanov*



We usually think of light propagating in straight line. However, everyone knows that light can reflect and refract, that is, change the direction abruptly. Can one actually bend the light, forcing it to go along curved lines? The answer is "yes" and, moreover, there is a general principle that explains all those phenomena from a unified perspective, known as Fermat's principle. It was formulated by Pierre de Fermat almost 400 years ago. We will discuss a few applications of Fermat's principle.

About the lecturer: *Sasha is a Professor in Department of Physics and Astronomy and a Deputy Director of the Simons Center for Geometry and Physics at Stony Brook University, NY.*
Sasha's research is in theoretical condensed matter physics and in mathematical physics. He is mainly interested in systems whose properties are defined by the laws of quantum physics. Some examples of such systems are superfluids, superconductors and Quantum Hall effect systems.
Sasha enjoys teaching physics and mathematics at different levels. He has a lot of experience in teaching school students in various summer camps and math circles.

The Unreasonable Effectiveness of Mathematics in the Natural Sciences
by *Alexander Kirillov*

"Mathematics is the language of science". This statement is so commonplace that we rarely question it — everyone knows that laws of nature (in particular, fundamental physical laws) can be described by mathematical formulas.

Few people realize that this is a relatively new idea, going back to the time of Galileo (16th century). He was one of the first people to apply mathematics to study of nature, thus turning "natural philosophy" into an exact science which we now call physics. This revolutionized physics; nowadays we take it for granted that any physical process can be described by mathematical formulas. Moreover, we came to expect that these formulas are nice and simple — such as $F = ma$ or $E = mc^2$.

But why is it so? Is it something fundamental about the world that the laws of nature are given by elegant mathematical rules? Or is it introduced by humans who try to study it?

Over 50 years ago famous physicist Eugene Wigner wrote a paper "The Unreasonable Effectiveness of Mathematics in the Natural Sciences", where he asked these questions. In my talk, I will present some of his thoughts — and add my own.

About the lecturer: *Alexander Kirillov is a professor in the Math Department of Stony Brook University. His research is in representation theory, quantum invariants of knots and low-dimensional manifolds, and Topological Field Theory. He has been working with high school children, teaching math circles and gifted classes, since his own high school graduation. In addition to math, he also enjoys hiking, volleyball, and robotics — he is the coach of Islandbots robotics club.*

Before Photoshop: Special Effects in the Age of Steam
by *Sergei Butkevich*

Since 1980s, special effects in movies are created using various computer techniques. But many of these "special effects" have been used quite effectively way before computers even existed. How did they do that? And if images and videos can be altered in almost any way imaginable, can we ever be sure that an image is genuine and not fake?

About the lecturer: *Sergey Butkevich holds a Ph.D. in Mathematics from Ohio State University. He is a Senior Quantitative Analyst at Renaissance Technologies, a quantitatively-oriented investment fund in Long Island, NY.*