SigmaCamp Lectures

August 14-21, 2016

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Opening lecture

The Primal Mind: Pre-Conscious Human Behavior and Social Dynamics

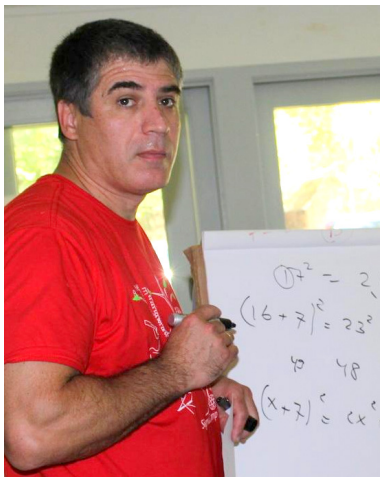
by *Lilianne R. Mujica-Parodi*

In the 17th Century, Descartes wrote "Cogito Ergo Sum": I think, therefore, I am. While animals presumably act according to instinct, as humans we tend to believe that we have self-awareness of our plans and actions. Here, citing historic and modern neuroscience experiments, we provide provocative evidence that humans act pre-consciously far more often than any of us, including Descartes, could have imagined..

About the lecturer: *Lilianne R. Mujica-Parodi is Director of the Laboratory for Computational Neurodiagnostics, and Associate Professor in Stony Brook University's Dept. of Biomedical Engineering. She also is Associate Neuroscientist at Massachusetts General Hospital/Harvard Medical School (Dept. of Radiology) as well as Research Affiliate at the MIT's McGovern Institute for Brain Research. Dr. Mujica-Parodi is the recipient of the Brain & Behavior Research Foundation's Young Investigator Award, the National Science Foundation's Career Award, as well as the White House's Presidential Early Career Award in Science and Engineering. Her research interests focus on the application of control systems engineering and complex systems analysis to neuroimaging, with neurodiagnostic applications to neurological and psychiatric disorders.*

Lectures

How Do Cats Land on Their Feet?
by *Sasha Abanov*



We will talk about rotational motion. We consider tops, gyroscopes and will end our discussion with physics of cats landing on their feet.

About the lecturer: *Professor, Department of Physics and Astronomy, Deputy Director of the Simons Center for Geometry and Physics, 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.*

Where Linguistics and Mathematics Meet: Semantics of Quantifiers
by *Andrei Antonenko*

In this lecture we will explore quantifiers - natural language expressions such as "every", "most", "some", etc. The theory of quantifiers was developed in the 1980 at the interface of logic, linguistics, and philosophy. In this theory, quantifiers are viewed as relations between subsets of the universe. For example, the sentence "Most birds fly" determines a relation between a set of birds and a set of fliers. We will talk about classification of quantifiers and their properties, and what is natural and can occur in the human language and what is not.

About the lecturer:*Andrei received his PhD in linguistics from Stony Brook University in 2012. He mostly works on theoretical syntax and semantics, exploring reflexive pronouns cross linguistically, in diverse languages such as English, Russian, Japanese, Chinese, Icelandic, Balinese. His other areas of research include sociolinguistics, dialectology, and*

non-standard varieties of English. Currently Andrei works as a Lecturer in Stony Brook University linguistics department. Andrei also teaches mathematics at SchoolNova.

Talk Around 'Time'
by *Michael Bershadsky*

How modern physics thinks about time, what is so special about it. How do we think about time in the context of special relativity? Why time always flow in one direction? We dream of time machine, can we go back in time?

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 Renaissance Technologies.*

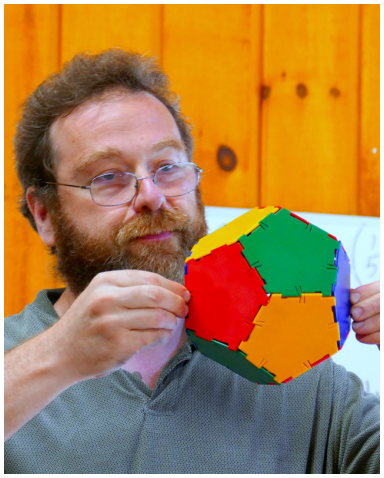
Art and Technology: a Way to Creativity or a Secret Weapon
by *Vicka Bershadsky*

Contemporary artists have embraced the new advances in technoligy to enhance and chang the world of art in the most creative an unexpected ways. Is this the latest trend? When did the artists shift away from trying to imitate life by their skill alone to using technology as a tool? The debate is open and the art world is buzzing with controversy. According to some, the technology came into play as a sceret tool a lot earlier than we can suspect. Let us try to analyze this argument and to see how sound it is.

About the lecturer: *Financial/Administrative Coordinator 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.*

Stirling's Formula
by *Pavel Etingof*

Stirling's formula is one of the most important formulas in mathematics. It allows one to precisely estimate the number $n! = 1 \cdot 2 \cdot ... \cdot n$ for a large number n, expressing it (amazingly!) in terms of universal constants $e = 2.71...$ and $\pi = 3.14....$ Namely, it says that n! is approximately equal to $(n/e)^n \cdot (2 \cdot \pi \cdot n)^{1/2}$ when n is large, in the sense that the ratio of these numbers approaches 1 as n gets large. We will derive Stirling's formula and discuss its applications. For example, we will derive the Central Limit Theorem, which explains why a vast universe of random phenomena are described by the celebrated Bell Curve.



About the lecturer: *Pavel Etingof is Professor of Mathematics in the Mathematics Department at MIT. Pavel received his Ph.D. in mathematics from Yale University. His research interests are noncommutative algebra, representation theory, and mathematical physics. In mathematics, he mostly enjoys the interplay between different fields (such as algebra and analysis), and between classical and modern mathematics. He has led mathematics research programs for high school students at the Clay Mathematics Research Academy and the Research Science Institute (RSI) at MIT. He co-founded the MIT-PRIMES program and has served as its Chief Research Advisor since 2010. When Pavel isn't doing math, he enjoys mycology and can be found identifying, collecting, and cooking mushrooms for fun(gi).*

Beyond Color: Infrared and Ultraviolet Photography
by *Sergey Butkevich*

When we take pictures with film or digital camera, we only capture visible light, which is a tiny portion of the electromagnetic spectrum. Can we take pictures using "invisible light"? Does this actually make any sense? We will discuss what colors are and how we see them, how photography works, and whether one can take pictures using infrared or ultraviolet light. The lecture will be accompanied by a workshop where the participants will be able to take infrared pictures using modified digital SLR cameras.

About the lecturer: *Sergey Butkevich received his Ph.D. in Mathematics from Ohio State University in 2000. He is currently a researcher and principal at Renaissance Technologies Corporation where he uses Math and Computer Science to study financial markets.*

Gravitational Waves—a New Window on the Universe
by *Sergei Dubovsky*

On February 11, 2016 the Laser Interferometer Gravitational wave Obsevratory (LIGO) announced the discovery of gravitational waves. Gravitational waves is one of the very first prediction of general relativity. However, it took 100 years for this prediction to be confirmed observationally. Why did it take so long? What did we learn from this discovery? What can we learn with the future gravitational wave observatories?

About the lecturer: *Sergei Dubovsky received his PhD in physics in 2001 from INR (Moscow, Russia). After serving as a junior research fellow at CERN, Harvard and Stanford in 2010 he joined the Center for Cosmology and Particle Physics at NYU, where he currently holds a position of an Associate Professor. Currently, he is also a Visiting Senior Faculty at the Perimeter Institute for Theoretical Physics (Waterloo, Canada). Sergei works at the interface of string theory, particle physics and cosmology.*

The Strange Power of Information
by *Anne-Marie Grisogono*

What exactly is information? It appears in both physics and information theory, but strangely, the most interesting and important aspect of information - its ability to carry meaning – is completely absent in those theories. Semantic information, i.e. information that carries meaning as opposed to simply being a non-random pattern, is absolutely central to life and to its ability to evolve and thrive. On the other hand if we think about the very early universe it is clear that there is no place (yet) for semantic information to exist. So it makes sense to ask: where did it come from? How did it arise?

About the lecturer: *Anne-Marie Grisogono is a physicist, now an Adjunct Professor in the Engineering Faculty of Flinders University in South Australia. Anne-Marie has worked in both academic and applied research, across a wide range of fields including defence, synthetic environments, and complex systems science.*

What Is a Random Sequence?
by *Alexander Kirillov*

If we look at these sequences of digits
010101010101
31415926535
5772156649
67396356809
most people would agree that the first one is not random, and neither is the second one. Do you think the last two are random? And what exactly the word "random" means? Can you give a definition of a random sequence? In this lecture we will discuss several approaches to this, going from simple probability theory to computational complexity and enthropy.

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.*

TBA
by *Maxim Kontsevich*

TBA

About the lecturer: *Maxim is a math professor at the Institut des Hautes Études Scientifiques, France. He received the Henri Poincaré Prize in 1997, the Fields Medal in 1998, the Crafoord Prize in 2008, the Shaw Prize and Fundamental Physics Prize in 2012, the Breakthrough Prize in Mathematics in 2014. His work concentrates on geometric aspects of mathematical physics, most notably on knot theory, quantization, and mirror symmetry.*

Introduction to Protein Structure and Function
by *Dima Kozakov*

The lecture provides an introduction to the proteins - major molecular building blocks of the living cells. We will focus on the physical-chemical basis of protein structure and function, including signal transduction, enzymatic catalysis, and gene regulation. The problems and current approaches to predicting protein structure including those using homology, energy minimization and modeling will be introduced. The future implications of our expanding biomolecular knowledge and of rational drug design will also be discussed.

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.*

Color, Dyes, and Fluorescence
by *Mark Lukin*

What is color? Why some substances are colored, and others are not? What does the word "fluorescencence" mean, and why fluorescent dyes are so important? We will discuss these and other questions, and will do some experiments to understand these phenomenae better.

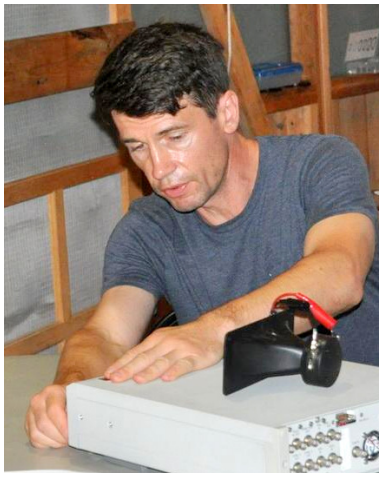
About the lecturer: *Mark is Research Assistant Professor, Pharmacology Department, Stony Brook University. The focus of Mark Lukin's scientific interest are nucleic acids (DNA and RNA). How does DNA get copied? What happens when DNA molecules breaks? To answer these, as well as many other questions, 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.*

From Pine Cones to Pin Codes
by *Nikita Nekrasov*

Phyllotaxis is the botanical system that regulates the placement of succesive leaves along a stem. RSA cryptographic algorithm is used in all banking transactions. The motion of planets around the Sun is governed by the laws of general relativity, which predict that the approximately periodic orbits slowly change in time in a so-called quasi-periodic fashion. The distribution of first digits of powers of two is uneven, 1 occurs 30% of time, while 9 only 4%. The same law (called Benford's law) is observed in many examples of real sets of numerical data, including statistics of voting. All these observations and phenomena revolve around one geometric object which the lecture will discuss.

About the lecturer: *Professor at Simons Center for Geometry and Physics. Nikita got his PhD from Princeton in 1996, then was a Junior fellow at the Harvard Society of Fellows at Harvard University, then a Robert. H. Dicke Fellow at Princeton University. In 2000 he became a permanent professor at the Institut des Hautes Études Scientifiques. In 2013, he moved to the Simons Center for Geometry and Physics at Stony Brook University as a full professor.*

How to Make the Brightest Beam of Light on Earth (and Pick the Color You Like)?
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 and 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 explain how the synchrotron light sources work.

About the lecturer: *Physicist, Photon Sciences Directorate, Brookhaven National Laboratory, NY. Boris 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.*

Tail Wagging the Dog.
by *Marina Polonskaya*

Zombie Creatures: What Happens When Animals Are Possessed by a Parasitic Puppet Master? From fungi to flies, some parasitic species have figured out how to control their host's behavior to get what they need.

About the lecturer: *Theoretical biophysicist by training, worked in molecular biology (University of Illinois at Chicago, Harvard Medical School and Stony Brook University), then made a sharp turn and became a Director of an academic enrichment program at Stony Brook. The program is known to many children in and around Stony Brook as SchoolNova. Ph.D.*

Chemistry of Explosives and Fireworks
by *Tanya Pyatina*

We will talk about basic principles, history and chemistry of explosives and reflect on greater and more diverse roles of molecules designated as explosives. We will also take a quick look at chemical reactions producing numerous colors, BANGS, CRACKLES and WHISTLES in fireworks. Perhaps by the end of the lecture we might just find ourselves a little more impressed by the remarkable chemical processes behind the explosive wonders.

About the lecturer: *After getting her Ph.D. in environmental engineering and chemistry at Caltech Tanya worked as a materials scientist at Schlumerbger service company. Presently she works at Brookhaven National Laboratory in Sustainable Energies Department creating materials with "self-healing" properties under extreme environments of geothermal wells.*

Introduction to Molecular Evolution and Phylogenetics
by *Igor Rogozin*

Phylogenetic analysis is an essential part of bioinformatics. I will discuss various applications of phylogenetic analysis, from origin of animals to human genetic diseases.

Introduction to Bioinformatics: Homology Searching in Genomes
by *Igor Rogozin*

In today's world, computers are as likely to be used by biologists as by any other professionals. Many of the tasks performed by such professionals are common to most of us: we all tend to write lots of memos and send lots of e-mails. However, besides these general tasks, biologists also use computers to address problems that are very specific to biologists. These specialized tasks, taken together, make up the field of bioinformatics. We analyze master plans of organisms (genomes). Information in genomes (DNA) we see as a four letter text.

About the lecturer: *Igor Rogozin has been working on various aspects of molecular evolution and comparative genomics as a research scientist at the National Center for Biotechnology Information NLM, National Institutes of Health (USA). He is also an Adjunct Lecturer in the Foundation for Advanced Education in the Science.*

Cyber Security Primer, Or How To Prevent Your Naked Pictures From Being Stolen From iCloud
by *Yuri Salkinder*

Seems that a week does not pass without news of a break-in into some major computer system. Sony, Target, HomeDepot, JPMorgan Chase Bank, nobody seems to be immune. We'll discuss different classes of attacks and attackers. Then we'll look at how computer systems are checked for their ability to defend against cyber attacks. Finally, we'll discuss what measures you could take to safeguard your personal information.

About the lecturer: *Yuri Salkinder has a PhD in Software Engineering from the Institute for Problems in Informatics of the Russian Academy of Sciences. His career spanned academia, telecommunications and financial technology. Yuri started in research in human-computer interaction, then moved on to help build software development tools for Voice response systems. He participated in creation of some standards for wireless messaging. Nowadays Yuri is dealing with messaging of another kind – the one that fuels electronic financial markets. He is currently a Managing Director at Bank of America Merrill Lynch, leading Electronic Trading Technology for Americas region.*

What Does Biology and Brain Compute?
by *Hava Siegelman*

Alan Turing suggested a computational model that describes how people think.. This model was taken forward to create the current computers we use. We can take this even further by considering other types of computational models toward future technology.

About the lecturer: *Hava is a Professor of computer science and brain sciences at the University of Massachusetts. She also serves as a program manager at DARPA (Defence Advanced Research Projects Agency). Hava received all her academic degrees in the field of Computer Sciences. Her book on computing beyond the Turing limit, has started the sub-field of super-Turing computation. She has just received the international Hebb award in recognition of her contribution to the understanding of biological learning.*

Why are Biomedical Science Results so Irreproducible?: An Introduction to Bayesian Analysis
by *Helmut Strey*

In recent years it has become evident that results in biomedical research are much less reproducible than expected. I will discuss some of the reasons for this trend. It seems that "standard" statistical modeling is insuficient to deal with this trend. As an alternative, I will introduce Bayesian Statistics and explain how it may be used to solve our current problem.

About the lecturer: *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.*

The Introduction to Stellar Astronomy: the Life of Stars
by *Inna Sus*

Born out of tons of gas and dust, stars need to spend their life under enormous pressure, to shine, and, eventually to finish with a huge explosion. Well, not every star finishes with a catastrophic explosion, but every one of them is born from gas, and dust and deep down every star feels enormous pressure, and they shine throughout the entire universe. Some are blue, some are red, some are big, some are small, some are young, some are old, some have temper, and some are calm. So what it takes to be a star? What makes them shine? What makes them lose temper? During this talk, we will become familiar with the basic ideas and techniques used in stellar astronomy to measure distances, temperatures, and composition. We will talk about stellar evolution and discuss why it is so important that we learn as much as we can about these beautiful orbs.

About the lecturer: *Inna is a physicist, mathematician and astronomer. She 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.*

Drunken Sailor, Einsein and How Molecules Move
by *Alexei Tkachenko*

A Drunken Sailor is walking the streets of Manhattan, making random turns. Little does he know that his Random Walk is a famous problem that had strong impact on modern Physics, Chemistry, Biology, Mathematics, Computer Science, and Financial Markets. This problem was a subject of Einstein's thesis, and of his most cited scientific papers. In this lecture, I will talk about the Random Walk Problem and the phenomenon of diffusion. As an example of its many uses, I will connect this problem to the physics of polymers, and the notion of fractals.

About the lecturer: *Alexei is a theoretical physicist at Brookhaven National Laboratory. He is 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 is one of the pioneers of theoretical studies of DNA/nanoparticle and DNA/colloidal systems. He also teaches physics at School Nova.*

Motion of Nanoparticles in Water and Biological Molecular Motors
by *Alexander Vologodskii*

Water has low viscosity for macroscopic objects but its viscosity is enormous for nanoparticles, such as biological macromolecules. Due to this viscosity the objects of microscopic world have no inertia in water. This means that nanoparticles stop directional motion nearly immediately after the moving force is eliminated. This fact has many fundamental consequences, and one of the most important is related to the work of biological molecular motors. In these motors the energy of chemical compounds is transformed into the directed movement, in particular the contraction of muscles. Due to the lack of inertia the physical principles governing this transformation have to be very different from the principles underlying the manmade macroscopic motors, like piston or jet engines. The internal thermal diffusion and allosteric transitions in motor proteins are two key elements of the motors. The chemical energy is not used in molecular motors to perform the mechanical work directly, like in the manmade motors, but instead it is used for rectifying the internal diffusion in the motor proteins. This process will be considered in some details and illustrated by examples of specific motor systems.

About the lecturer: *Alexander Vologodskii graduated Moscow Institute of Physics and Technology in 1972. From the very beginning of his career he specialized in molecular biophysics. For fifteen years he worked at the Physics Laboratory at the Institute of Molecular Genetics, Moscow. Over these years Vologodskii pioneered many computational approaches to physical properties of DNA molecules. He received his Ph.D in 1975 and the highest Russian scientific degree, Doctor of Science, in 1985. In 1992 he relocated to the United States. From 1996 till 2012 Vologodskii ran a biophysical research lab at New York University. His scientific interests were concentrated around physical properties of DNA molecules and enzymes that perform topological transformations in circular DNA. He published more than 100 research paper and two books, "Topology and Physics of Circular DNA" (1992) and "Biophysics of DNA" (2015). Currently Vologodskii is a freelance science writer.*

What Else is out There?, or Fascinating Biology of the Invisible Organisms
by *Slava Yurchenko*

Under the relatively new name Excavata, a substantial fraction of all eukaryotic life on the Earth is hidden. Recent extensive analyses of biodiversity indicate that up to $\frac{3}{4}$ of current eukaryotic diversity is hidden in tiny, often uncultivable protists with all the macroscopic organisms representing only a few offshoots. I will talk about these creatures and some amazing adaptations they have evolved.

About the lecturer: *Associate Professor, Department of Biology and Ecology, University of Ostrava, Czech Republic. Slava Yurchenko is a molecular biologist by education, training and the way of thinking. After spending several years in some of the best universities in the United States, he has recently established his own laboratory in the Czech Republic. His group is tackling some of the fundamental questions of life, such as evolution of eukaryotes. He is also involved in research on parasites and their relationships with the host.*

The Bernoulli Principle: It Is Everywhere.
by *Igor Zaliznyak*

Why does the curve ball curve? How does the boomerang fly? What is there in common between a chimney and an airplane? How does a spray atomizer function? The Bernoulli effect is something we frequently experience in our everyday life, but rarely pay attention. We shall explore these and other questions by understanding why and how the Bernoulli principle works. Hands-on demonstrations will include a simple Magnus-effect-flyer and unusual forces created by moving air.

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 9th and 10th grade math at SchoolNova.*