FALL 2015 PROGRAMS, WORKSHOPS & SEMINARS

The 2015-16 academic year has been off to a great start with new developments in the Simons Center for Geometry and Physics. This fall the Center had two semester-long programs. The first one was Moduli Spaces and Singularities in Algebraic and Riemannian Geometry organized by Simon Donaldson (Simons Center), Henry Guenancia (Stony Brook), Hans-Joachim Hein (Maryland), Radu Laza (Stony Brook), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourne), Yan Fyodorov (Queen Mary), Alice Guionnet (MIT), Jon Keating (Bristol), Mario Forrester (Melbourn...
As one of the Simons Center’s trustees, how do you see the role of the Center? Any future programs caught your eye? Does the Center feel even closer to you now that one of your numerous notable former research students, Simon Donaldson, is here?

Geometry and theoretical physics have always complemented each other and more so in the last 40 years, as I know in my own research. Despite their increasing proximity, it is still true that mathematicians and physicists develop with different sets of intuitions. Research often involves analogies with known areas and if you are familiar with, for example, quantum field theory from your student days, it gives a different window on pieces of mathematics from someone like me with a conventional mathematical training. But, in fact, mathematicians are equipped with the formal knowledge of many abstract areas which when put into a physical setting can yield something big. There are two workshops coming up I hope to be involved with. One is Generalized Geometry where I am one of the organizers, and another is on Higgs bundles5. Both in fact have their roots in what I was thinking about in Stony Brook all those years ago.

Could you speak a little about the ‘Miss Marple’ approach? (“...seeking to learn about an area of mathematics by seeing how it impinges on a particular problem, which by itself might seem unimportant”)? What are the most favorite examples?

You know, when Miss Marple is faced with a murder to solve, she always refers back to some relatively trivial issue in her home village of St. Mary Mead. My approach to research is usually based on understanding how relatively simple examples or features can represent in miniature far more general theories, if looked at in a novel way. You need both the vision to attempt something new but also the confidence to see that it is compatible with what you already know. I suppose one example are the Higgs bundle equations – gauge-theoretic equations on a Riemann surface which in 1983 I was convinced had a future, if only that they were analogues of the monopole and instanton equations I had worked on earlier. But it was the link with minimal surfaces (actually not quite the same equations) that kept me going. Once I could see that the 19th century result on associated families was the same as the twistor approach I was familiar with, I could start investigating in earnest.

I suppose another example is my earlier work on magnetic monopoles where I was convinced that the complex structure on the space of straight lines in Euclidean space was the right framework. Probing around I could see that minimal surfaces again had a natural role here (I didn’t realize at the time that it was a geometric reformulation of Weierstrass’s theorem in its r666666) and that made me realize that it was a profitable, and natural, approach to pursue.

String theory provides an abundance of mathematical challenges. Do you think other physics disciplines could develop stronger interaction with mathematics?

This is the perennial question. I think it requires exceptional individuals to make it work and we have been fortunate in having people such as Edward Witten in string theory talking to us mathematicians over the past four decades. It’s an important question for the Center too, not to be type-cast in the long term. Currently the most important thing is to produce excellent science, whatever the subject.

How important in science is taste?

I think the communication of ideas is the most important aspect, and it is made easier if the two people involved have the same taste. I can recognize that there are areas of mathematics which are vitally important but I know I can make no contribution there because they are not to my taste. This is partly because of the choices I made in my education, but every individual looks at things in a different way and I see no harm in that if it means you do better work and present it more convincingly. Of course not everything you do in writing a paper is necessarily attractive or tasteful—you sometimes have to make compromises and get your hands dirty—but if the result is natural, easily understood and useful in some context one usually feels it was worthwhile.

What else, besides physics, helps you in the process of mathematical research?

I am attracted by simply-stated questions about very concrete objects which nevertheless have a trail which leads back into some serious mathematics. I wrote a paper a few years ago about nodal sets of spherical harmonics and the icosahedron which was really a question about vector bundles on elliptic curves. Or the paper I wrote about Poncelet’s theorem and Einstein’s equations. The first paper was an observation which as far as I know has never been used, the second actually provided the basis for a new example of a positively curved manifold. Something in a completely different area.

You mention your interest in cinema—what is your opinion on the recent filmmakers’ interest in science, and did you enjoy its results, such as The Theory of Everything or The Imitation Game?

When a scientist reads a newspaper report about something he or she knows it is inevitably wrong on several accounts, and that’s why I don’t really like biopics about mathematicians. I didn’t like The Imitation Game because it seemed to suggest that everything was done by Turing and his close circle when there were thousands at work in Bletchley Park. I began to learn about this from my undergraduate mathematics tutor at Jesus College before everything became publicly known. What the film did do for me was to make me read the biography of Turing written by my colleague Andrew Hodges which is very good.4

I did like The Theory of Everything, though Roger Penrose here in Oxford (who is portrayed in the film) told me all about the facts they got wrong (“that lecture was not in London”, “I wasn’t there at that time”). In Cambridge I shared a College room with Stephen Hawking and knew him quite well, which meant that I found Eddie Redmayne’s portrayal of him utterly amazing. It also made a good story, since there was a coherent view—that of his wife.

So, I don’t really go to the cinema for science or science fiction. Except maybe when Woody Allen quotes the second law of thermodynamics! (Twice in fact: “Hannah and her Sisters” and “Whatever Works”).

THE HIDDEN MESSAGE OF GEOMETRY AND PHYSICS OF PINE CONES\textsuperscript{1}

By Nikita Nekrasov, Professor Simons Center for Geometry and Physics

The very existence of life as we know it is based on a few seemingly fine-tuned coincidences between the parameters determining the strength of fundamental interactions. One of such remarkable coincidences is the existence of a resonance state in carbon-12, due to which a triple of alpha particles (nuclei of helium) can fuse in the interior of stars to give rise to most of the carbon in the Universe.

Since organic chemistry is based on carbon, and we as living beings are based on organic chemistry, the fact that a tiny change in the energy of resonance state in carbon-12, due to which a triple of alpha particles can fuse in the interior of stars to give rise to most of the carbon in the Universe, would lead to the disappearance of most of the periodic table of elements seems like a hint from heaven.

Yet Nature might be giving us other hints as to why it is that of physically unrealistically small dimension, is the 2-torus. It can be hand-made starting with a parallelogram and identifying the sides (see Fig. 1). The geometry of the 2-torus is determined by the lengths of sides of the parallelogram and the angle between them. The Calabi-Yau manifolds, which are believed by some to hold the secrets of the Standard Model physics, typically have hundreds of such length and angle parameters.

It seems hopeless to find a principle selecting one set of such parameters over another. This led some physicists and philosophers to abandon the quest for understanding the origin of the parameters of Nature, resorting to the so-called anthropic principle: these parameters are such that the sufficiently complex organic life is possible to form to observe these parameters. In some versions there is not one Universe, but rather a multitude of co-existing multi-verses, with different physics in different baby universes, and we happen to be in one, in which we can exist.

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example, these numbers are 8 and 13 on Fig 5. One can repeat these experiments with sunflower seeds and other plants (Fig. 6-7). Despite numerous attempts to explain the Fibonacci phyllotaxis using evolutionary, biological or chemical arguments, the puzzle remained pretty strong until the end of the last century, until physicists Levitov (1991) and Douady and Couder (1992) and others found both physical arguments and physical systems exhibiting similar behavior for the similar reasons.

To present the argument of Levitov let us simplify the problem by assuming the pine cone has the shape of a cylinder. The spikes grow one at a time, linearly, and arrange themselves in a spiral around the cylinder. Now, the important physical assumption is the hierarchy of time scales: it takes a long time to grow another spike (it must contain the seed of a future pine), so during that time the spikes which are already on the cone have time to re-arrange themselves so as to minimize the discomfort, caused by stress. The latter can be quantified as a sort of energy function, which depends on the mutual discomfort, which can be quantified as the energy depending on the conformal structure of the two-torus: the ratio of the lengths of the sides and the angle between them. Such energy function, generically, has a minimum for the tori corresponding to the hexagonal lattices, and a saddle point for the square lattices. Moreover, the growth of new spikes acts effectively as the vertical compressing force. Levitov’s argument: for a fixed area of a fundamental domain the lattice, which is changing slowly due to the pressure of the newcoming seeds, re-arranges itself, passing near the saddle points and the local minima of the energy function. The numbers of the spirals change sequentially passing through all the Fibonacci pairs \((m,n) \iff (n, m+n)\). Returning to the important question of the inner workings of the Universe, the message hidden in the shape of the pine cones still needs to be deciphered further. The numbers of spirals may correspond to the charges of some extended objects (D-branes in string theory) wrapping non-contractible cycles in the internal Calabi-Yau, forcing its shape to assume one of the attractor values (the local minima of the energy function). What plays the role of the compressing force? Perhaps, it is the cosmological expansion of the Universe?...

Mathematically, a sequence of points on cylinder aligned along a spiral is the same thing as a lattice on a two-plane (Fig. 9). The latter determines a two-torus, by cutting the plane along the lattice edges and identifying the opposite sides. The idea of Levitov (which we shall not present in full) is that the configuration of spikes minimizes their mutual discomfort, which can be quantified as the energy depending on the conformal structure of the two-torus: the ratio of the lengths of the sides and the angle between them. Such energy function, generically, has a minimum for the tori corresponding to the hexagonal lattices, and a saddle point for the square lattices. Moreover, the growth of new spikes acts effectively as the vertical compressing force. Levitov’s argument: for a fixed area of a fundamental domain the lattice, which is changing slowly due to the pressure of the newcoming seeds, re-arranges itself, passing near the saddle points and the local minima of the energy function. The numbers of the spirals change sequentially passing through all the Fibonacci pairs \((m,n) \iff (n, m+n)\). Returning to the important question of the inner workings of the Universe, the message hidden in the shape of the pine cones still needs to be deciphered further. The numbers of spirals may correspond to the charges of some extended objects (D-branes in string theory) wrapping non-contractible cycles in the internal Calabi-Yau, forcing its shape to assume one of the attractor values (the local minima of the energy function). What plays the role of the compressing force? Perhaps, it is the cosmological expansion of the Universe?...

Dr. Bassler aimed to convince an audience of nearly 250 life science and medicine students to the Simons Center for Geometry and Physics in an ongoing effort to enhance the Center’s intellectual activity and bring greater awareness of recent and impactful scientific discoveries to the local community. Each edition of the series includes a technical talk, a high school lecture, and a lecture for the general public.

For this edition of the series, the Center was pleased to invite the “Bacteria Whisperer,” Dr. Bonnie Bassler, Squibb Professor in Molecular Biology and Chair of the Department of Molecular Biology at Princeton University, to give the lectures. Dr. Bassler is a member of the National Academy of Sciences and a Fellow of the American Academy of Arts and Sciences; she has received special recognition from the World Cultural Council, named L’Oreal-UNESCO For Women in Science Awards Laureate for North America in 2012 and was one of the American Society for Microbiology’s USA Science Engineering Festivals’ Nifty Fifty Speakers in 2010. This year, Dr. Bassler and Everett Peter Greenberg of the University of Washington were awarded the Shaw Prize in Life Science and Medicine for their discovery of quorum sensing, the topic of her series of lectures.

Dr. Bassler’s visit to the Simons Center began on October 1, 2015 with the high school and general public lectures titled “How Bacteria Talk To Each Other.” In these lectures, Dr. Bassler aimed to convince an audience of nearly 250 high school students and teachers, and an audience of 150 members of the community that, despite 400 years of believing that bacteria were nothing more than single-minded, asocial recluses, they can in fact communicate with each other, they are multi-lingual, and that devoting one’s life to studying bacteria is rewarding.

Dr. Bassler opened her talk by humorously informing her audience that a human body contains about ten times more bacterial cells than human cells and in regards to DNA, a person has 100 times more bacterial genes than human genes. She laughed with the audience as she said ‘at the best, you’re 10 percent human, but more likely about one percent human, depending on which of these metrics you like.’
complete individually. Dr. Bassler’s studies disprove what scientists have believed for centuries, and suggest that bacteria were in fact the first social creatures on Earth.

Once the audience understood the concept of quorum sensing, Dr. Bassler shared further studies proving that bacteria communicate with two different chemical languages. The first, a chemical language that says “me”, allows bacteria to communicate with others in their species, and the second, a language that says “you”, allows bacteria to achieve interspecies communication. The two languages allow bacteria to count how many of “me” and “you” there are and synthesize the information to carry out a task based on which party is in the majority.

At the end of the lecture the audience was surely convinced that bacteria could communicate, but how is devoting one’s life to studying bacteria practical? Dr. Bassler enthusiastically shared her hopes for the future, that scientists could interfere with quorum sensing and create new medicines and antibiotics. Her thoughts opened the eyes of her audience to the huge implications that these studies can have on medical science and engineering. She closed the lecture by encouraging her younger audience to pursue a life of science, calling it “the greatest life in the world,” which was followed by a roar and applause from the audience.

The next edition of the Della Pietra Series will be held from February 8 – 10, 2016 featuring Professor Tadashi Tokieda, University of Cambridge.

For more information about this lecture series, or to watch the videos, please visit: scgp.stonybrook.edu/archives/172538.

For more information about the Della Pietra Lecture Series, please visit: scgp.stonybrook.edu/della-pietra-lecture-series.

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**PUZZLE TIME**

**THE DRUNKARD AND POLICEMEN**

Adapted by Alexander Abanov, Deputy Director, Simons Center for Geometry and Physics

The following problem is a modification of the “drunkard’s walk” puzzle, a famous lore in the mesoscopic physics community. It illustrates the concept of “rare fluctuations” — an important idea in statistical mechanics and solid state physics. Its solution and discussion will be presented in the next issue of the SCGP newsletter.

**PROBLEM:**

A drunkard walks randomly in an idealized city. The city is effectively infinite and its streets are arranged in a square grid (e.g., Manhattan without Broadway). At every intersection, the drunkard chooses one of the four possible routes with equal probability. Let us assume that the length of each block in the city is 1, and the time it takes for the drunkard to go from one intersection to another is \( T \). The drunkard keeps wandering until he meets one of the policemen who are stationary and positioned randomly at some intersections. Assuming that the fraction of intersections with policemen is small and equal to \( p \), compute the probability of the drunkard still walking around the city in large time \( t \).

**Remark:** It is important to average over the “ensemble”, i.e., possible placements of the policemen. For example, one might consider many drunkards starting their walks at various points throughout the city and ask about the fraction of drunkards who “survived” after time \( t \).
This past Fall the Simons Center Gallery featured a solo exhibition of work by Manfred Mohr, internationally acclaimed pioneer of digital art, which was on view from September 10th through November 12th, 2015. Curated by Dr. Lorraine Walsh, Artistic Director and Curator of the Gallery, this exhibition was honored to feature Mohr’s early digital drawings, produced at Brookhaven National Laboratory in 1969, alongside some of Mohr’s newer works, which were produced specifically for this exhibition.

The approximately 2,000 visitors to the exhibition included students and faculty from Stony Brook University, visiting scholars and researchers at the Simons Center for Geometry and Physics, and local community members.

Works on view in the Simons Center Gallery were on loan from the bitforms gallery in New York City, the artist himself, and notably, Mohr’s seminal early digital drawings P-018-mf_1-10, produced at Brookhaven National Lab, are on loan from the Anne and Michael Spalter Digital Art Collection. These drawings represent some of the first digitally executed art ever created.

For more information or to propose an exhibition, please visit: scgp.stonybrook.edu/art.
**METHOD**

Preheat oven to 450° Fahrenheit.

In a large glass or metallic bowl, sift all of the dry ingredients together. Set aside.

Using a sharp knife, cut butter into small die sized pieces. Using a hand washing motion, rub butter and flour mixture together until shaggy, being careful not to overwork and melt butter. The shaggier, the better.

Add milk, and knead just to incorporate the ingredients. This will look very uneven and sloppy, but it works.

Using a spoon, ladle a small amount of the batter on a parchment lined, and greased sheet pan. Bake for approximately 20 minutes or until very golden brown.

A few minutes before the biscuits are ready, in a heavy bottomed saucepot, melt the butter and the honey glaze over a low heat. The mixture should bubble slightly. Be very careful, as this is very hot. Set aside.

Remove biscuits from oven, let cool for a few minutes, and carefully drizzle the tops with the glaze. Sprinkle with raw sugar, and enjoy!

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**INGREDIENTS**

Yield: 8 Biscuits

<table>
<thead>
<tr>
<th>Amount</th>
<th>Ingredient</th>
</tr>
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<tbody>
<tr>
<td>2 Cups</td>
<td>All Purpose Flour</td>
</tr>
<tr>
<td>4 Teaspoons</td>
<td>Baking Powder</td>
</tr>
<tr>
<td>1 Teaspoon</td>
<td>Kosher Salt</td>
</tr>
<tr>
<td>1 Teaspoon</td>
<td>Cream of Tartar</td>
</tr>
<tr>
<td>½ Cup</td>
<td>Unsalted Butter, cold</td>
</tr>
<tr>
<td>2/3 Cup</td>
<td>Whole Milk</td>
</tr>
<tr>
<td>2 Teaspoons</td>
<td>Sugar</td>
</tr>
</tbody>
</table>

**GLAZE**

<table>
<thead>
<tr>
<th>Amount</th>
<th>Ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ Cup</td>
<td>Honey</td>
</tr>
<tr>
<td>½ Cup</td>
<td>Butter, melted</td>
</tr>
</tbody>
</table>

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**SCGP CAFÉ’S CULINARY MASTER SERIES**

The Simons Center for Geometry and Physics is pleased to announce the 3rd edition of the Culinary Master Series. The Spring 2016 series will be made up of four themed cooking demonstrations by Executive Chef, Paolo Fontana.

Join us at the SCGP Café on the following dates:

**FEBRUARY 9TH 2016**

**OUR FAVORITE THINGS**

**MARCH 8TH**

**COMFORT FOODS**

**APRIL 12TH**

**THE INCREDIBLE EDIBLE EGG**

**MAY 3RD**

**SPRING FORWARD**

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**INFORMATION**

For $35.00 per person, you will have a chance to taste the dishes and enjoy wine pairings. Space is limited so reserve your spot now!

For more information please go to: scgp.stonybrook.edu/scgp-culinary-master-series.

For questions, call 631-632-2881.

To watch videos of past classes, please go to: scgp.stonybrook.edu/archives/12752.
The Simons Center for Geometry and Physics encourages mathematicians and physicists to spend time at the Center while on sabbatical leave from their faculty positions at home institutes. Visitors to the SCGP enjoy maximal research freedom and have many opportunities to participate in the activities of the Center and to collaborate with the Center’s other visitors, faculty, and members of Stony Brook University’s departments of Math, and Physics and Astronomy.

We invite those interested to contact the SCGP by providing a C.V., an explanation of their reasons for wanting to visit, desired dates, and their financial needs. Preference will be given to extended visits and to organizers and participants in the Center’s programs.

Please contact Elyce Winters at ewinters@scgp.stonybrook.edu