THE FIELDS INSTITUTE MAJOR THEMATIC PROGRAM

CALABI–YAU VARIETIES: ARITHMETIC, GEOMETRY AND PHYSICS

FINAL REPORT

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1. Impact and Scientific Outcome of the thematic program

Our stated goal of the thematic program is to enhance our understanding of Calabi–Yau manifolds from several points of view, i.e., arithmetic, geometry and physics. Enormous amounts of activities have taken place during the program, contributing to the fruitful interactions among mathematicians and theoretical physicists (string theorists). Through our activities, mathematics and theoretical physics around Calabi–Yau manifolds have reached new heights in

our understanding. This includes the Gross–Siebert program, homological mirror symmetry, wall-crossing phenomena, quasi-modularity of various enumerative invariants, to name a few.

The program centered around two distinguished lecture series (by Kontsevich and Voisin) and 5 workshops (the first of which introductory). Together with the pre-workshops, these cornerstones of the program sparked two- or three-week-long bursts of activity which made all participants literally feel the current progress on Calabi-Yau varieties and the neighboring areas of mathematics and physics. As distinct highlight we would like to feature three events:

- the public lecture by Kontsevich which gave a brilliant introduction to high impact mathematics to a huge audience filling the auditorium to the very last seat, and his subsequent lectures on the hottest topics at the interface of mathematics and string theory;
- the joint workshop held at the Perimeter Institute which created a unique atmosphere of excitement among all participants, mathematicians and physicists.
- the series of lectures by Voisin which featured current developments on Hodge theory, and its applications to Calabi-Yau varieties and string theory.

The workshops have brought mathematicians and string theorists of the top rate to the Fields Institute (and also to the Perimeter Institute). As a distinguished aim, the organizers have made special efforts to encourage young researchers (graduate students, postdoctoral fellows) and women to participate in each workshop and also in the pre-workshop graduate courses. To this end, we made sure to secure extra funding from NSF (Introductory workshop, and workshops 1, 2, and 4 through Gross and Laza), Perimeter Institute and PIMS to support the above mentioned groups of researchers and at the same time invite outstanding speakers such as Candelas, Zagier, Fukaya, Costello, Ruan, Zaslow, Hori, Soibelman, Peters, Morrison, Katzarkov and Zuo.

The outstanding research environment of the Fields Institute has enabled us to recruit excellent postdocs for the program, with only one of the initial offers turned down. Even more so, the postdocs have flourished during the program, despite many of the organizers' unfortunate absence for long periods, running a high level postdoc seminar twice a week and starting promising projects and collaborations in large number.

The concentrated graduate courses given in the pre-week of each workshop have turned out to be a huge success. These courses have served as entry points into mathematics and physics around string theory. For dissemination, it is planned that the lecture notes of these courses will be published in the Fields Communications Series. The anticipated contributions include papers on the following subjects:

- The Gross-Siebert program (Filippini, Overholser, Ruddat, Zhu)
- Non-abelian Hodge theory (Garcia-Raboso, Rayan)
- Enumerative invariants (Rose, van Garrel)
- Zeta-functions and L-series of Calabi–Yau varieties (Perunicic)
- Introduction to Hodge theory (Thompson, Harder, Filippini, Ruddat)
- Physics on mirror symmetry (Quigley)
- Algebraic cycles and K-theory (Kerr)

The timing of the program was just right. Both mathematicians and string theorists have benefited from each others company. Through direct contact, both camps have tried to reach the common ground of understanding on whatever topics on the table. In the name of all participants, we would like to thank the Fields Institute for giving us the

opportunity to run this great program and bundle the latest research activities on Calabi–Yau varieties in arithmetic, geometry and physics.

All in all, the major thematic program was a huge success bringing the very high profile mathematicians and string theorists, as well as many aspiring young researchers to the Fields Institute. We are especially proud that many women mathematicians and string theorists took part in the program.

The Fields Institute has encouraged us to apply for the Retro Workshop in the near future, which hopefully brings together again all the Fields postdoctoral fellows and young and established researchers who took part in the program.

2. Funding Received

The Fields Institute Major Thematic Program on Calabi–Yau Varieties: Arithmetic, Geometry and Physics, has received fundings from the following agencies and research institutes.

- Fields Institute $350,000.
- Fields Institute covered expenses for Distinguished Lecture Series by M. Kontsevich, and Coxeter Lecture Series by C. Voisin.
- NSF grant $30,000 for Summer School, Workshops 1 and 2 to cover expenses of US based participants. The principal applicant was Mark Gross and the fund was administered by University of California San Diego.
- Perimeter Institute $30,000 for Workshop 3.
- NSF grant $20,000 for Workshop 4 through Radu Laza's CAREER Award to cover US based participants and Laza's expenses. The fund was transferred from Stony Brook University to the Fields Institute and administered by the Fields Institute.
- PIMS CRG Program "Geometry and Physics" for Workshop 4 for expenses from participants from the western Canada.

The organizers are extremely grateful for all the support received for making the program such an enormously successful endeavor.

3. Distinguished Lecture Series and Coxeter Lecture Series

Maxim Kontsevich (IHES) gave a series of three lectures on October 15, 16 and 17. The titles and abstracts of his lectures were:

• **What is Tropical Mathematics?** (Public lecture).

Abstract: In tropical mathematics the usual laws of algebra are changed, the subtraction is forbidden, the division is always permitted, and 1+1 is equal to 1. Analogs of usual geometric shapes like lines, circles etc. are replaced by new figures composed of pieces of lines. I will try to explain basics of tropical algebra and geometry, its relation with more traditional domains, and its role in mirror symmetry which is a remarkable duality originally discovered in string theory about 20 years ago.

• **Quivers, cluster varieties and integrable systems**

Abstract: I'll describe a new approach to cluster varieties and mutations based on scattering diagrams and wall-crossing formalism. The central role here is played by certain canonical transformation (formal change of coordinates) associated with arbitrary quiver. Also, a complex algebraic integrable system under some mild conditions produces a quiver, and the associated canonical transformation is a birational map.

• **Fukaya category meets Bridgeland stability**

Abstract: Bridgeland's notion of stability in triangulated categories is believed to be a mathematical encoding of D-branes in string theory. I'll argue (using physics picture) that partially degenerating categories with stability should be described as a mixture between symplectic geometry and pure algebra. Spectral networks of Gaiotto, Moore and Neitzke appear as an example.

Coxeter Lecture Series

Clarie Voisin (Jussieu) gave a series of three lectures on November 13, 14 and 18. The titles and abstracts of her lectures were:

• **The canonical 0-cycle of a K3 surface**

Abstract: Beauville and I proved that an algebraic K3 surface S has a 0-cycle which is canonically defined modulo rational equivalence, and has the property that the intersection of any two divisors on S is proportional to it.

I will review a number of properties of this cycle, some of which have been discovered by Huybrechts in his study of spherical objects in the derived category of S.

• **On the Chow ring of Calabi–Yau manifolds**

Abstract: I will describe generalizations, some of which are conjectural, of the canonical ring of a K3 surface to higher dimensional hyper-Kaehler manifolds or to more general Calabi-Yau manifolds. For Calabi-Yau hypersurfaces X, for example, I show that the intersection of any two cycles of complementary nonzero dimension is proportional to the canonical 0-cycle (the intersection of a line with X). In the hyper-Kaehler case, the canonical ring is generated by the divisor classes and the Chern classes of the tangent bundle and it is conjectured that the cycle class map is injective on it.

• **Decomposition of the small diagonal and the topology of families**

Abstract: The results on the Chow ring of K3 surfaces and of Calabi-Yau hypersurfaces are obtained by decomposing the small diagonal in the Chow group of the triple product X^3. In the case of a K3 surface, this decomposition has the following consequence on families $f : S \to B$ of projective K3 surfaces parametrized by a quasi-projective basis B: Up to shrinking B to a dense Zariski open set, there is a multiplicative decomposition of Rf_*Q, that is a decomposition as the direct sum of its cohomology sheaves, which is compatible with cup-product on both sides. This is reminiscent to what happens with families of abelian varieties, and is very restrictive on the topology of the family.

4. Summer School

In July and August, there were summer school activities for the program. Visiting graduate/undergraduate students, visiting postdoctoral fellows, and senior visiting researchers took part in the program. Senior visitors included Mark Gross (San Diego), Bernd Siebert (Hamburg), Klaus Hulek (Hannover). Visiting graduate students included Atsushi Kanazawa (UBC), Yuecheng Zhu (Texas Austin), Alex Molnar (Queen's), Man-Wai Cheung (San Diego), Andrew

Harder (Alberta), Sam Selmani (McGill). The total number of registered participants for the summer school was **20**. A number of Summer Undergraduate Research Students attended some Postdoctoral Seminars. The list of participants is attached below in Section 11.

5. The Concentrated Graduate Courses

The concentrated graduate courses were organized in the pre-week of each workshop in the purpose of preparing graduate students, postdoctoral fellows and members of the thematic program for the forthcoming workshop(s).

★ The Concentrated Graduate Course for the Workshop 1 : Modular Forms around String Theory, September 9–13, 2013 at Fields Institute Room 230.

The total number of registered participants was **21**.

Here is the list of speakers and their titles.

• Clingher, Adrian: Nikulin involutions in the context of lattice polarized K3 surfaces
Abstract: I will review the notion of Nikulin involution on a K3 surface X. Then, I will discuss a special type of such involution, obtained from translations by a section of order-two in a Jacobin elliptic fibration.

• Doran, Chuck: Introduction to K3 surfaces
Abstract: I will describe geometric constructions, periods, and moduli for K3 surfaces, by way of introduction to the more technical lectures by Thompson, Harder, and Clingher.

• Harder, Andrew: Lattice theory and K3 surfaces
Abstract: Following the publication of the proof of the global Torelli theorem for K3 surfaces, it became evident that large portions of the theory of K3 surfaces and their moduli reduce to the theory of a specific even unimodular lattice of signature $(3, 19)$ and its associated orthogonal group. In this talk, I will discuss some basic lattice theory and outline how it can be used to prove geometric statements about K3 surfaces.

• Perunicic, Andre: (1) Arithmetic Techniques in Mirror Symmetry
Abstract: Mirror pairs of certain Calabi-Yau manifolds defined over finite fields have their numbers of rational points closely related. In this talk I will explain p-adic techniques which can be used to count rational points on such mirror pairs. We will compare the the number of rational points on a manifold and its mirror modulo p.
(2) Mirror Symmetry for zeta functions
Abstract: As an application of the point-counting techniques from the previous lecture, I will present some relations of zeta functions for mirror pairs of Calabi-Yau manifolds defined over finite fields.

• Rose, Simon: (1) Introduction to modular forms (and their enumerative significance)
Abstract: We will introduce the notion of a modular form, with a focus on those forms which arise in an enumerative setting.
(2) Introduction to Gromov-Witten theory
Abstract: We will outline the motivation and definition of Gromov-Witten invariants, with a particular focus on the Gromov-Witten theory of $\mathbb{P}^2$ and its role in counting plane curves. We will also try to talk about many of the interesting structures that come naturally from these constructions, and highlight the role of Calabi-Yau three-folds.

• Thompson, Alan: Moduli of K3 surfaces
Abstract: I will discuss the construction of the moduli space of K3 surfaces and some of its properties, before moving on to talk about degenerations of K3 surfaces and the compactification problem.

• **Zhou, Jie: Special Kähler geometry and BCOV holomorphic anomaly equations, 1 and 2**

Abstract: In this talk, first we will introduce the basics of mirror symmetry, special Kähler geometry and BCOV holomorphic anomaly equations. We will then construct the special polynomial ring and sketch how to solve the BCOV anomaly equations using the polynomial recursion technique, by showing some examples.

★ Concentrated Graduate Course for Workshop 2: Enumerative geometry and Calabi–Yau varieties, and for Workshop 3: Physics around mirror symmetry, October 7–11, 2013 at Fields Institute, Room 230.

The total number of registered participants was **28**.

Here is the list of speakers and their titles.

• **Sara Filippini (1), and Man-Wai Cheung: The tropical vertex group, scattering diagrams and quivers**

Abstract: The tropical vertex group $\mathbb{V}$ introduced by Kontsevich-Soibelman plays a role in many problems in algebraic geometry and mathematical physics. The group itself can be understood in very different ways. In the approach due to Gross, Pandharipande and Siebert, a central role is played by tropical curves in $\mathbb{R}^2$ and their enumerative invariants. This approach leads to a number of applications. On the one hand, correspondence theorems connect factorizations in $\mathbb{V}$ with Gromov–Witten theory. On the other hand, these tropical methods when combined with results of Reineke, allow to relate Gromov–Witten theory to the topology of moduli spaces of quiver representations. First we will describe the tropical vertex group and in particular scattering diagrams. Then we will sketch the connection with tropical curves and, if time permits, with moduli spaces of quiver representations.

• **Sara Filippini (2): Introduction to toric degenerations**

Abstract: A toric degeneration is (roughly speaking) a family of varieties whose central fiber is a union of toric varieties glued pairwise torically along toric prime divisors. It is possible to encode all information about the degenerating variety into certain combinatorial data, namely an affine manifold with singularities together with a compatible piecewise-linear function. We will introduce singular affine manifolds and the construction of toric degenerations and discuss the scattering process.

• **Michel van Garrel (1): Survey of Donaldson–Thomas and Pandharipande–Thomas theory**

Abstract: This talk is a survey of the definition and properties of Donaldson–Thomas (DT) and Pandharipande–Thomas (PT) invariants for a Calabi–Yau threefold X. The focus will be on overviewing some of the modern developments of the theory. The weighted Euler characteristic approach will be mentioned. It will be explained how PT invariants yield a (conjectural) construction of integer-valued BPS state counts. Time permitting, it will be discussed how DT and PT invariants are naturally realized as counts of objects in the bounded derived category of coherent sheaves on X. In that setting, the wall-crossing formula for going from DT to PT corresponds to a change of stability condition.

(2): Introduction to Logarithmic Geometry and Log Stable Maps

Abstract: We give an introduction to logarithmic geometry which will be fundamental knowledge for the conference talks by Abramovich, Chen and Gross. We define log stable maps and explain why a stable curve is a smooth curve in the logarithmic sense.

(3): Logarithmic Gromov-Witten Theory

Abstract: Logarithmic Gromov–Witten (GW) invariants are a generalization of GW invariants to a logarithmically smooth situation. One major advantage is a clarification of the degeneration formula, although its definitive form is still work in progress. In this talk, we define these invariants and motivate them from the perspective of the degeneration formula.

• **Peter Overholser (1): Tropical Curves and Disks**

Abstract: I will present a few perspectives on tropical geometry, emphasizing concrete descriptions and properties of so called "parametrized" tropical curves, disks, and trees. These objects will play a central role in the discussion of mirror symmetry for $\mathbb{P}^2$.

(2): Mirror Symmetry for $\mathbb{P}^2$

Abstract: I will give a sketch of Gross's construction of mirror symmetry for $\mathbb{CP}^2$. The presentation will rely heavily on the tools introduced in the week's earlier discussion of tropical geometry.

• **Nathan Priddis (1),(2): Geometric Quantization and its applications to Gromov–Witten theory**

Abstract: In the first talk I will try to motivate the methods that are employed in geometric quantization, such as Feynman diagrams and Givental's formalism. In the second talk I will introduce the methods more explicitly and try to give a few examples of how it relates to GW theory.

Callum Quigley (1),(2): Physics of Mirror Symmetry: The Basics

Abstract: I will review the ideas that lead physicists to Mirror Symmetry: $N = 2$ superconformal field theories, their chiral rings and moduli spaces. Then I will discuss some simple examples and applications.

• **Simon Rose : An introduction to Gromov-Witten theory**

Abstract: We will go over (quickly!) the motivation and ideas behind Gromov–Witten theory, focusing in particular on the case of $\mathbb{P}^2$. Heavy emphasis will be on examples and concrete computations as much as possible.

• **Helge Ruddat (1): Introduction to the Fukaya Category**

Abstract: We define Lagrangian Floer homology and the Fukaya category. We give some examples and explain the idea of the proof of homological mirror symmetry for the elliptic curve.

(2): Computation of Gromov-Witten invariants via Tropical Curves

Abstract: We show that the counting of rational curves on a complete toric variety which are in general position relative to the toric prime divisors coincides with the counting of the corresponding tropical curves. The proof relies on degeneration techniques and log deformation theory and is a precursor to log Gromov-Witten theory.

★ A Concentrated Graduate Course for Workshop 4 : Hodge Theory in String Theory, November 11–15, 2013 at Fields Institute, various locations.

The total number of registered participants was **31**.

Here is the list of speakers and their titles.

• **Filippini, Sara: An introduction to Hodge theory**

Abstract: We give an introduction to the basic concepts of Hodge theory, including the notion of a pure Hodge structure and the Hodge filtration. We then discuss the uses of this theory in the study of cohomology, including the Hodge decomposition and the Lefschetz decomposition.

• **Garcia–Raboso, Alberto: Introduction to nonabelian Hodge theory: Higgs bundles and local sytems I**

Abstract: Hodge theory can be extended to cohomology with coefficients in nonabelian groups. For GL_r, this results in a correspondence between flat vector bundles (which, by the Riemann-Hilbert correspondence, are the same as local systems), and so-called Higgs bundles. Over smooth projective varieties, the latter are not only holomorphic, but in fact algebraic, objects. We will discuss this correspondence and how it is useful (among other things) for constructing variations of Hodge structure.

• **Harder, Andrew: The Kuga–Satake construction**

Abstract: There is a well known construction of Kuga and Satake which embeds the transcendental Hodge structure of any algebraic K3 surface into the second cohomology group of an abelian variety. I will give an overview of this construction and show how it can be turned into an explicit geometric correspondence in some situations.

• **Kerr, Matt: Algebraic and arithmetic properties of period maps**

Abstract: The three talks will cover Mumford–Tate groups and boundary components, as well as limits of normal functions and generalized Abel-Jacobi maps.

• **Laza, Radu: Classical period domains**

Abstract: I will discuss the classification of Hermitian symmetric domains, the connection between HSD's and VHS, and some examples of moduli spaces uniformized by HSD's.

• **Peters, Chris: Period domains and their differential geometry revisited**

Abstract: Griffiths' period domains classify polarized Hodge structures; they have a pure Lie-theoretic description as reductive domains. This can be used to translate differential geometric properties on associated bundles into properties for associated Lie-algebras. In particular, this gives an explanation for the curvature properties for the natural invariant metric on such domains. These results were all known in the seventies of the last century and due to Griffiths and Schmid. They obtained them making heavy use of detailed Lie-theory. The proposed approach avoids this.

Mixed Hodge structures can also be described by period domains, but these are no longer reductive. The transformation group acting transitively on such a domain is no longer semi-simple and the natural metric in general is no longer invariant. This complicates the curvature calculations. Nevertheless, in special cases which are of interest in geometric applications one can deduce some properties analogous to what happens in the pure case.

The description of mixed period domain was also known for some time and is due to Usui and Kaplan. The curvature calculations were started by Pearlstein. In a joint work in progress we are extending this result and give some applications.

It is my intention to explain this in 2 lectures focusing mainly on the pure case.

• **Rayan, Steve: Introduction to nonabelian Hodge theory: Higgs bundles and local systems II**

Abstract: We will discuss interesting geometric aspects of the moduli spaces for the objects introduced in Part I in Garcia–Raboso's talk.

• **Ruddat, Helge: Degenerations of Hodge structures**

Abstract: This talk concerns the behaviour of geometric variations of Hodge structures near singular fibers in a family as studied by Schmid-Steenbrink. We define the canonical extension of a vector bundle with connection from the punctured disk to the disk and then extend variations of Hodge structures by extending the Gauss-Manin connection. The limiting object to be filled in is a mixed Hodge structure. We define nearby and vanishing cycles sheaves and state various properties of these.

• **Schütt, Matthias: (1) Picard numbers of quintic surfaces**

Abstract: The Picard number is a non-trivial invariant of an algebraic surface which captures much of its inner structure. It is a fundamental problem which Picard numbers occur within a given class of surfaces. For the prototype example of quintics in $\mathbb{P}^3$, I will show that all numbers 1 and 45 indeed occur as Picard numbers. The main technique consists in arithmetic deformations.

(2): 64 **Lines on quartic surfaces**

Abstract: In a 1943 paper, Benjamino Segre claimed that a smooth complex quartic surface contains at most 64 lines. However, his arguments turn out to be incomplete, and at some places wrong. I will present joint work with S. Rams which uses elliptic fibrations to give a complete proof of the corresponding statement over any field of characteristic other than 2 and 3.

• **Thompson, Alan: Variations of Hodge structure and the period map**

Abstract: We begin by defining the period map, which relates families of Kahler manifolds to the families of Hodge structures defined on their cohomology, and discuss its properties. This will lead us to the more general definition of a variation of Hodge structure and the Gauss-Manin connection.

The first two talks of Claire Voisin's Coxter Lecture Series were given during this week.

6. Workshops

There were five workshops during the thematic program.

★ The Introductory Workshop on Calabi-Yau Varieties: Arithmetic, Geometry and Physics August 26-30, 2013 at Bahen Building Room 1180

The organizers: Same members as the program and scientific organizing committee listed above.

The total number of registered participants was **32**. The list of participants is attached below in Section 11.

The Introductory Workshop for the thematic program Calabi-Yau Varieties: Arithmetic, Geometry and Physics was a 5-day warm-up session aimed at graduate students, postdoctoral fellows and members of the program. Lectures were mostly of pedagogical nature, introducing various aspects of the subject areas of the program. Lectures covered topics from arithmetic, geometry and string theory. Each lecturer gave up to three lectures on chosen topics explaining basic concepts and problems.

Gross, Ruddat and Siebert gave a series of six lectures on the Gross–Siebert Program. Hulek covered topics on moduli spaces in his two lectures, and Laza surveyed degenerations and compactifications in his two lectures. Doran, Filippini, and Whitcher gave introduction to K3 surfaces and Calabi–Yau threefolds covering various topics which include Hodge structures, lattice polarized K3 surfaces, toric constructions, and mirror symmetry. Doran's lectures were delivered by Andrew Harder and Alan Thompson. Talks of Yui and Whitcher covered some arithmetic aspects of Calabi–Yau varieties of dimension 2 and 3. Thomas presented his proof about "thinness" of the hypergeometric monodromy groups associated to seven families of Calabi–Yau threefolds with $h^{1,1} = 1$ previously considered by Doran–Morgan and Chen–Yang–Yui.

Here is the list of speakers and their tiltes:

- **Charles Doran**: *From K3 to CY3*
- **Sara Angela Filippini**: *Hodge structures on Calabi–Yau manifolds*
- **Mark Gross**: *Introduction to the Gross-Siebert program*
- **Klaus Hulek**: *Irreducible holomorphic symplectic manifolds–geometry and moduli*
- **Radu Laza**: *Degenerations and compactifications*
- **Helge Ruddat**: *Examples of the Gross–Sierbert program*
- **Bernd Siebert**: *Introduction to the Gross-Siebert program*
- **Hugh Thomas**: *Thin monodromy subgroups of* $Sp(4, \mathbf{Z})$
- **Johannes Walcher**: *Calabi-Yau Varieties: Physics*
- **Ursula Whitcher**: *(1) The Greene–Plesser mirror construction and the applications to congruent zeta-functions, and (2) The Batyrev–Borisov construction to Delgachev's mirror symmetry for K3 surfaces*
- **Noriko Yui**: *Calabi-Yau Varieties: Arithmetic (Modularity of various kinds)*

★ Workshop 1: Modular Forms around String Theory, September 16–21, 2013 at Fields Institute

Room 230.

The organizers: Charles Doran (Alberta), Matthias Schütt (Hannover) and Noriko Yui (Queen's)

The total number of registered participants: **43**. The list of participants is attached below in Section 11.

The Workshop 1 "Modular Forms Around String Theory" was devoted to the arithmetic aspects of Calabi-Yau varieties around string theory. The subjects of the workshop may be classified into not clearly disjoint sets of the following topics: Modular, quasimodular, mock modular, Siegel and Jacobi modular forms, and their appearance in string theory, topological string theory, modularity (automorphy) of Galois representations, and arithmetic questions, mirror symmetry, mirror maps, arithmetic aspects, conformal field theory, possible relations to monstrous moonshine, holomorphic anomaly equations, Picard–Fuchs differential equations and periods, Feynmann diagrams and integrals, toric geometry and applications to Calabi-Yau varieties.

Doran and Clingher considered modular forms associated to lattice polarized K3 surfaces, while the talk of Malmendier talk gave physics behind those K3 surfaces. Gao presented his joint work with Yau on the construction of extremal bundles on Calabi–Yau manifolds. Talks by Zagier and Zhou were concerned with holomorphic anomaly equations and quasimodular forms. Topics on modular forms in String Theory were covered by the talks by Pioline, Murthy and Ruan. On the arithmetic side, talks were presented by Candelas, Kelly, Kudla, Wan, Whitcher, Yui and Zagier. Variants of Gromov–Witten invariants were given by Rose, Ruan and Zhou. Hosono discussed mirror construction of a determinantal quintic Calabi–Yau threefold. Murthy's second talk touched uopn Mattieu moonshine, Modular forms arising from string amplitudes were covered by the talks of Pioline, Murthy, Zagier and Zhou.

Here is the list of speakers and their titles.

• **Candelas, Philip**: *(1) Puzzles to do with the zeta-function for the quintic threefold, and (2) The lines in the Dwork pencil of quintic threefolds*

• **Clingher, Adrian**: *Modular forms associated to K3 surfaces endowed with lattice polarizations of high Picard rank*

• **Doran, Charles**: *Families of lattice-polarized K3 surfaces with monodromy*

• **Gao, Peng**: *Extremal bundles on Calabi-Yau manifolds*

• **Hosono, Shinobu**: *Mirror symmetry of determinantal quintics*

• **Kelly, Tyler**: *Berglund–Hübsch–Krawitz mirrors via Shioda maps*

• **Kudla, Steve**: *Another product formula for a Borcherds form*

• **Malmemdier, Andreas**: *Heterotic/F-theory duality and lattice polarized K3 surfaces*

• **Murthy, Sameer**: *(1) Quantum black holes, wall crossing, and mock modular forms, (2) Mathieu moonshine, mock modular forms and string theory*

• **Pioline, Boris**: *Rankin-Selberg methods for closed string amplitudes*

• **Rose, Simon**: *Towards a reduced mirror symmetry for the quartic K3 surfaces*

• **Ruan, Yongbin**: *(1) and (2): Mirror symmetry and modular forms*

• **Wan, Daqing**: *(1) Rational points on a singular CY hypersurface, and (2) Mirror symmetry for the slope zeta function*

• **Whitcher, Ursula**: *Mirror quartics, discrete symmetries, and the congruent zeta function*

• **Yui, Noriko**: *Automorphy of Calabi–Yau threefolds of Borcea–Voisin type*

• **Zagier, Don**: *(1) Quasimodular forms and holomorphic anomaly equation, and (2) Some number theory coming from string amplitude calculations*

• **Zhou, Jie**: *Gromov-Witten invariants and modular forms*

★ Workshop 2: Enumerative Geometry and Calabi-Yau Varieties, October 15-19, 2013 at Fields Institute Room 230.

The organizers: Mark Gross (San Diego), Radu Laza (Stony Brook), Jaume Gomis (Perimeter), and Shing-Tung Yau (Harvard)

The total number of registered participants: **56**. The list of participants is attached below in Section 11.

There has been a huge amount of progress in the last several years towards understanding mirror symmetry from a mathematical perspective. Divergent points of view on mirror symmetry, such as homological mirror symmetry, the Strominger-Yau-Zaslow conjecture, and calculations of various invariants and their generating functions, have been converging to produce a unified point of view. This involves aspects of algebraic, symplectic and tropical geometry. Topics within these three fields with close connections featured in the workshop: Various new invariants and their relationships, including Gromov-Witten invariants, their logarithmic (relative) generalizations, invariants of Landau-Ginzburg models, Donaldson-Thomas invariants, Gopakumar-Vafa invariants, and others, The A- and B-model sides of mirror symmetry via degenerations of Calabi–Yau varieties, Recent progress on mirror symmetry at higher genus, Current approaches to proving homological mirror symmetry, Understanding the structure of the Fukaya category, Quivers, Cluster varieties, Wall-crossing formulas, The Gross–Siebert program, New correspondence theorems (between tropical and holomorphic geometry), Calabi–Yau manifolds and integrable systems.

Here is the list of speakers and their titles:

- **Abramovich, Dan**: *The decomposition formula for logarithmic Gromov-Witten invariants*
- **Abouzaid, Mohammed**: *Formality of Fukaya categories from disc counts*
- **Chris Brav**: *Hamiltonian local models for symplectic derived stacks*
- **Jim Bryan**: *π-stable pairs and the crepant resolution conjecture in Donaldson–Thomas theory*
- **Qile Chen**: *Very free curves on Fano complete intersection*
- **Yaim Cooper**: *The geometry of stable quotient spaces in genus one*
- **Kevin Costello**: *Quantization of BCOV theory on Calabi–Yau manifolds*
- **Diaconescu, Duiliu**: *Parabolic refined invariants and Macdonald polynomials*
- **Sarah Filippini**: *Refined curve counting and wall-crossing*
- **Mark Gross**: *Introduction to Logarithmic Gromov–Witten invariants*
- **Kenji Fukaya**: *Perturvation of constant maps, String topology and Perturbative Chern–Simons Theory*
- **Kontsevich, Maxim**: *(1) What is tropical mathematics? (2) Quivers, cluster varieties and integrable systems, and (3) Fukaya category meets Bridgeland stability*
- **Ruan, Yongbin**: *A mathematics theory of gauged linear sigma model*
- **Ruddat, Helge**: *Speculations on Mirror Symmetry for Riemann surfaces*
- **Soibelman, Yan**: *3-dimensional Calabi-Yau manifolds and Hitchin integrable systems*
- **Tseng, Hsian-Hua**: *Mirror theorem, Seidel representation, and holomorphic disks*
- **Zaslow, Eric**: *Legendrian knots and constructible sheaves*
- **Alexsey Zinger**: *Mirror Symmetry for stable quotients invariants*

★ Workshop 3: Physics around Mirror Symmetry, October 21-25, 2013 at Perimeter Institute Room 400.

The organizers: Vincent Bouchard (Alberta), Jaume Gomis (Perimeter Institute), Sergei Gukov (CalTech), Johannes Walcher (McGill), and Shing-Tung Yau (Harvard)

The total number of registered participants: **36**. There were many students from Perimeter Institute attending the workshop, but not registered. The list of participants is attached in Section 11.

This was a joint workshop with the Fields Institute for the thematic program.

The workshop discussed recent progress in the physics of mirror symmetry, a subject that has evolved in close relation with mathematical advances in the field of algebraic geometry, especially on Calabi-Yau varieties, leading to the genesis of many groundbreaking ideas.

This event brought together leading physicists and mathematicians to discuss the various approaches to the subject, and to collaborate on the extraction of new mathematics from the improved understanding of the powerful physical theories.

Here is the list of speakers and their titles.

- **Borot, Gaeten**: *Blobbed topological recursion*
- **Bouchard, Vincent**: *Quantum curves and topological recursion*
- **Couso, Ricardo**: *Resurgent transseries and the holomorphic anaomaly*
- **Diaconescu, Emanuel**: *Coisotropic brandes, surface defects and mirror symmetry*
- **Favero, David**: *Derived categories and variations of GIT quotients*
- **Gaiotto, Davide**: *Algebraic structures in massive* $(2,2)$ *theories*
- **Gualtieri, Marco**: *(Colloquium) The stokes groupoids*
- **Gualtieri, Marco**: *Generalized complex geometry*
- **Hori, Kentaro**: *Exact results in two-dimensional* $(2,2)$ *supersymmetric gauge theories with boundary*
- **Kachru, Shamit**: *Some simple extensions of Mathieu Moonshine*
- **Karigiannis, Spiro**: *The mathematics of* G_2 *conifolds for* M*-theory*
- **Klemm, Albrecht**: *On refined stable pair invariants for del Pezzo surfaces and the* $1/2$ *K3*
- **Melnikov, IIarion**: *Hybrid conformal field theories*
- **Okuda, Takuya**: *Exact results for boundaries and domain walls in* $2d$ *supersymmetric theories*
- **Quigley, Callum**: *Heterotic flux geometry from* $(0,2)$ *gauge dynamics*
- **Soibelman, Yan**: *Wall-crossing structures*
- **Walcher, Johannes**: *Extensions and monpdromy in open string mirror symmetry*

★ Workshop 4: Hodge Theory in String Theory, November 18-22, 2013 at Fields Institute Room 230.

The organizers: Charles Dorn (Alberta), Radu Laza (Stony Brook), David Morrison (Santa Barbara), and Johannes Walcher (McGill)

The total number of registered participants: **54**. The list of participants is attached below in Section 11.

This was a joint workshop with PIMS CRG Program "Geometry and Physics"

Hodge theory has played an important role in understanding the interaction between mathematics and physics over the past two decades. For instance, the predictions of mirror symmetry can be understood as expansions of the period integrals at the boundary of the moduli space of complex structures. This workshop aimed to survey and explore the interaction between Hodge theory and physics in the understanding of Calabi-Yau varieties. Specifically, we focussed on the study of moduli spaces of Calabi–Yau varieties and their compactifications from the perspective of period maps, with applications to various string dualities. Conversely, we expect that ideas from physics explored in the workshop will lead to new insights on the mathematical side.

Topics included: Degenerations of Hodge structures, Compactifications of period domains, Period maps, Picard–Fuchs differential equations, Hodge theory and algebraic cycles, Arithmetic properties of periods, String theory and Hodge theory

Here is the list of speakers and their titles.

- **Ballard, Matt**: *Griffiths' residue theorem via Landau–Ginzburg models*
- **Charles, Francois**: *Families of rational curves on holomorphic symplectic fourfolds*
- **Dettweiler, Michael**: *Construction of differential equations of Calabi–Yau type and Hodge theory*
- **Doran, Chuck**: *Landau–Ginzburg models of Fano threefolds and moduli spaces of K3 surfaces*
- **Garbagnati, Alice**: *Calabi–Yau threefolds of Borcea–Voisin type*
- **Katzarkov, Ludmil**: *Mixed Hodge structures and phantoms*
- **Kerr, Matt**: *Algebraic cycles and local quantum cohomology*
- **Malmendier, Andreas**: *Multi-parameter families of K3 surfaces from Seiberg–Witten curves and hypergeometric functions*
- **Morrison, David**: *(1) Variations of Hodge structure, Gromov–Witten invariants and the Gamma class, and (2) Clemens–Schmid and mixed Hodge structures in string theory*
- **Movasati, Hossein**: *A common frame work for automorphic forms and topological partition functions*
- **Mustata, Anca**: *The Dwork pencil of quintic threefolds*
- **Pearlstein, Greg**: *Naive limits of Hodge structure*
- **Peters, Chris**: *Two isomorphic classical domains and related geometric moduli spaces*
- **Sacca, Giulia**: *Calabi–Yau manifolds and relative Jacobians of linear systems on surfaces with trivial Kodaira dimension*
- **Ususi, Sampei**: *Studies of closed/open mirror symmetry for quintic threefolds through log mixed Hodge theory*
- **Voisin, Claire**: *(1) Decomposition of the small diagonal and the topology of families, (2) Varieties of power sums and divisors on the moduli space of cubic fourfolds*
- **Walcher, Johannes**: *On 2-functions and their framing*
- **Zuo, Kang**: *On Shimura curves in Torelli locus of hyperelliptic curves*

7. Postdoctoral Seminars

Aside from concentrated graduate courses and workshops, Postdoctoral Seminars were held twice a week on Tuesdays and Thursdays during the thematic program. Also a study seminar on "Derived Algebraic Geometry" met sporadically on Fridays during the program. Here is the list of speakers and their titles for Postdoc seminars.

- **van Garrel, Michel**: *Ramifications of a formula for Gromov–Witten invariants*, July 4, 2013.
- **Rose, Simon**: *Orbifold reduced Gromov–Witten theory, and curve-counting on Abelian srufaces*, July 9, 2013.
- **Ruddat, Helge**: *Conifold transitions and SYZ mirror symmetry*, July 11, 2013.
- **Thompson, Alan**: *Families and moduli of K3 surfaces and Calabi-Yau threefolds*, July 16, 2013.
- **Filippini, Sara**: *Hodge structures of Calabi–Yau type and special geometry*, July 18, 2013.
- **Overholser, Douglas (Peter)**: *Tropical Landau–Ginzburg potentials and semisimple Frobenius manifolds*, July 23, 2013.
- **Rayan, Steve**: *Some aspects of Higgs bundles on curves*, July 25, 2013.
- **Perunicic, Andrija**: *Arithmetic aspects of Berglund–Hübsch duality*, July 30, 2013.
- **Kolpakov, Alexander**: *Hyperbolic polytopes and manifolds in dimensions beyond three*, August 1, 2013.
- **Zhu, Yuecheng**: *Compactifications of moduli of abelian varieties and mirror symmetry*, August 6, 2013.

• **Kanazawa, Atsushi**: *Calabi–Yau threefolds of type K and mirror symmetry*, August 8, 2013.
• **Garcia-Raboso, Alberto**: *A non-abelian Hodge theorem for twisted vector bundles*, August 13, 2013.
• **Amir-Khosravi, Zavosh**: *Classifying a rigid family of abelian surfaces*, August 15, 2013.
• **Whang, Jun Ho (Peter)**: *Introduction to higher genus mirror symmetry*, August 20, 2013.
• **Hulek, Klaus**: *Stable cohomology of compactifications of A_g*, August 22, 2013.
• **Gao, Peng**: *Chern numbers of stable CY bundles and DRY conjecture*, September 5, 2013.
• **Filippini, Sara**: *Refined curve counting and the tropical vertex*, October 1, 2013.
• **Rose, Simon**: *Tropical mirror symmetry for the elliptic curve*, October 3, 2013.
• **van Garrel, Michel**: *Modularity of generating functions of stable pair invariants for K3 surfaces*, October 29, 2013.
• **Perunicic, Andrija**: *Borisov's restatement of Berglund–Hübsch duality and associated arithmetic considerations*, October 31, 2013.
• **Zhu, Yuecheng**: *Donaldson–Thomas invariants and wall-crossing formulas*, November 5, 2013.
• **Rose, Simon** : *Computing the Gromov–Witten invariants of elliptically fibred CY3s over a Del Pezzo surface*, November 7, 2013.
• **Molnar, Alexander**:*Generalized Borcea–Voisin constructions with a view towards Mirror Symmetry*, Novermber 26, 2013.
• **Thompson, Alan**:*Plane sextics and hyperbolic diagrams*, November 28, 2013.
• **van Garrel, Michel**:*Integrality of relative BPS state counts of toric del Pezzo surfaces*, December 3, 2013.
• **Ruddat, Helge**:*Constructing homology cycles in a CY threefold by hand*, December 5, 2013.
• **Overholser, Douglas (Peter)**:*What is motivic measure?*, December 10, 2013.
• **Filippini, Sara**:*Berglund–Hubsch for elliptic curves*, December 12, 2013.
• **Perunicic, Andrija**:*Examples of the Calabi–Yau/Landau–Ginzburg correspondence* , December 17, 2013.

Calabi–Yau Derived Algebraic Geometry Seminar

• **van Garrel, Michel**: *Introduction and motivation for Derived Algebraic Geometry*, August 9, 2013.
• **Overholser, Douglas (Peter)**: *Simplicial commutative rings, I*, August 16, 2013.
• **Filippini, Sara**: *Simplicial commutative rings, II*, August 23, 2013.
• **Amir-Khosravi, Zavosh**: *The cotangent complex*, September 6, 2013.

8. Postdoctoral Fellows, Graduate and Undergraduate Students, and their activities

The thematic program: Calabi–Yau Varieties: Arithmetic, Geometry and Physics had seven postdoctoral fellows supported by the Fields Institute. They were: **Sara Filippini, Michel van Garrel, Peter Overholse, Andre Perunic, Simon Rose, Helge Ruddat**, and **Alan Thompson**. Simon Rose was a Jerald Marsden Postdoctoral Fellow, and Alan Thompson was (and will be) a Fields–Ontario postdoctoral fellow.

Besides the aforementioned postdoctoral fellows, many postdoctoral fellows from University of Toronto took part in the program. They included: Alberto Garcia-Raboso, Steve Ryan, Amir-Khosravi Zavosh, Fedor Soloviev. Peng Gao (Stony Brook) was a visiting postdoctoral fellow.

Postdoc seminars were organized by Simon Rose in a twice-a-week basis, and also a study seminar was run successfully once a week.

We continue with activity reports of the postdoctoral fellows.

Filippini, Sara (Fields PDF)

I have mainly worked on Berglund–Hübsch–Chiodo–Ruan mirror symmetry for elliptic curves, and made significant progress in comparing this construction with the classical and homological versions of mirror symmetry which are both known in this case. Moreover, in collaboration with C. Doran, I am investigating the relation between the (local) mirror map and certain open Gromov–Witten invariants for a toric Calabi–Yau manifold. Both projects profited greatly from my stay at Fields Institute for the Thematic Program on Calabi–Yau varieties which provided a challenging and stimulating, as well as welcoming, academic environment.

As a Fields Postdoctoral Fellow I was invited to give talks for the "Oberseminar: Algebraische Geometrie" at Universität Zürich, "Workshop 2 on Enumerative geometry and Calabi–Yau varieties" at Fields Institute, and for the Canadian Mathematical Society Winter meeting in Ottawa. Furthermore, from July 29 to August 2 2013, I visited Professor Charles Doran at University of Alberta, Edmonton (AB).

Overholser, Peter (Fields PDF)

Over the past few months I have been able to show that certain tropical invariants are closely related to classical Gromov–Witten invariants for $\mathbb{P}^2$. The result uses scattering diagrams and Barannikov's construction of mirror symmetry. A paper on the subject is in preparation.

I gave a talk at the University of Alberta Geometry and Physics Seminar on Monday, December 16th. The title of the talk is "A tropical descendent Landau-Ginzburg potential."

Perunic, Andre (Fields PDF)

Aside from attending the workshops, seminars and other events which are part of the program, I've continued the project that I started in my thesis on arithmetic aspects of Berglund-Hubsch-Krawitz (BHK) duality. In particular, myself and my adviser Marco Aldi have provided an arithmetic version of Borisov's vertex algebra restatement of BHK duality and recovered one of the results from my thesis in this new setting. As that project was completed and it is in final stages of editing before distribution. The paper is titled "Arithmetic aspects of Bergund–Hb̈sch–Krawitz duality". The results from this endeavor was presented at the CMS meeting in Ottawa in the session of "Modular Forms and Physics", in December 2013.

I have also decided to learn more about the Landau–Ginzburg/Calabi–Yau correspondence. Igave a talk about this on December 17 Fields postdoc seminar.

I have also started learning about modularity of non-rigid Calabi–Yau threefolds defined over $\mathbb{Q}$ in a joint project with Professor Yui.

Rayan, Steve (PDF at University of Toronto)

My main interests are the geometric and arithmetic properties of moduli spaces. I am chiefly interested in the moduli space of Higgs bundles, which is a distinguished quasiprojective Calabi-Yau variety. During the thematic program, I have sharpened and extended my results on Betti numbers of twisted Higgs moduli spaces at low genus, using generalizations of Nakajima quiver varieties. These results confirm predictions from physics due to Chuang, Diaconescu, and Pan (Commun. Numb. Th. Phys. 5 (2011) 1-56). I have also started a project on higher-genus mirror symmetry using the framework of Higgs bundles and spectral curves. This is joint work with Helge Ruddat, a colleague who I met through the thematic program. Talks my D.-E. Diaconescu, L. Katzarkov, and Y. Soibelman during the program's workshops have helped to inform this project. Prior to the Hodge Theory in String Theory Workshop, A. Garcia-Raboso and I gave a mini-course on nonabelian Hodge theory.

Publications during thematic program: "Co-Higgs bundles on $\mathbb{P}^1$", New York J. Math. 19 (2013), 925–945. Preprints during thematic program: http://arxiv.org/abs/1309.7014 [arxiv.org]

Rose, Simon (Fields PDF)

I have submitted two papers for publication: One paper (Counting Hyperelliptic curves on Abelian surfaces with Quasi-modular forms) which arose from my thesis work to the journal Algebraic Geometry (Foundation Compositio Mathematica), as well as a joint paper with Noriko Yui (Elliptic Calabi-Yau threefolds over a del Pezzo Surface [arXiv:1312.0911]) which has been submitted to the Proceedings of the MPIM in honour of Professor Hirzebruch.

During my time at Fields, I have given talks at the Queen's Algebraic Geometry seminar (November 17th. Title: Tropical Mirror Symmetry for Elliptic Curves), a talk at the CMS winter meeting in Ottawa (December 8th. Title: Towards a reduced Mirror Symmetry for quartic K3 surfaces), as well as numerous talks at Fields.

Ruddat, Helge (Fields PDF)

During my time in Toronto so far, I finished a paper on perverse curves
http://arxiv.org/abs/1309.1803
that I reported about at the enumerative geometry workshop (October 16–20). A perverse curve is the critical locus of the Strominger–Yau–Zaslow fibration of a Calabi-Yau 3-fold equipped with the structure of a cohomological mixed Hodge complex. I proved that for mirror dual Batyrev–Calabi-Yau's, the associated perverse curves have dual Hodge numbers. Perverse curves are expected to relate to mirror symmetry for varieties of general type (one of my previous works).

Furthermore, I have been working on the project "conifold transitions and toric degenerations" that I reported on in the postdoc seminar in July. I have been able to find the right affine cohomology group that governs the obstructions to smoothings and resolutions of conifold points. The goal is to give a comprehensive account of conifold transitions in the Gross–Siebert program.

Thompson, Alan (Fields–Ontario PDF)

During the last semester at Fields, I have spent most of my time working on two collaborations. The first, with A. Clingher, C. Doran, A. Harder, J. Lewis and A. Novoseltsev, is concerned with the study of K3-fibred Calabi-Yau threefolds and their moduli. So far this collaboration has produced two manuscripts. The first, "The 14th Case VHS via K3 Fibrations", was written largely before my arrival at Fields, but I have made substantial additions to it during my time here, including improvements to several of the results and the addition of an entire new section. It is now posted on arXiv:1312.6433 [mathAG].

The second manuscript, "Families of Lattice Polarized K3 Surfaces with Monodromy", was conceived during a trip I made to the University of Alberta in August and is now very close to completion: we have only one set of calculations left to finish. The paper is now posted on arXiv:1312.6434 [mathAG]. My second collaboration is with V. Alexeev and is concerned with the study of compactifications for the moduli space of K3 surfaces of degree two. This has been a long-running project, but we have made significant steps forward during my stay at Fields, especially during a trip I took to the University of Georgia to visit V. Alexeev in September. We have already proved a number of publishable results, but are hoping to strengthen them before releasing a paper.

Aside from this, I have made a number of trips to collaborate and speak about my work. I have visited the University of Alberta twice, first in August and again in November, to meet with my collaborators there. During the second trip I also gave a talk to the PIMS geometry and physics seminar, which was simultaneously broadcast to the University of British Columbia. In addition to this I visited the University of Georgia in September to meet with V. Alexeev, whilst there I gave a talk to the University of Georgia algebraic geometry seminar. Finally, in December I attended the CMS meeting in Ottawa, where I gave a talk on my work in the session on modular forms and physics.

van Garrel, Michel (Fields PDF)

The research directions explored during the stay at the Fields Institute concern mirror symmetry relating to del Pezzo surfaces. Denote by S a del Pezzo surface and by E a smooth anti canonical divisor on it, i.e. an elliptic curve. For toric S, logarithmic mirror symmetry for the pair (S, E), at least computationally, was established. This is continuation

of work by Takahashi for the projective plane. The logarithmic invariants of the A-model are the relative BPS state counts of (S, E), which were introduced by Gross–Pandharipande–Siebert. It was shown how these invariants are calculated via the variation of mixed Hodge structure on the B-model, as established by Konishi-Minabe. A geometric explanation for this phenomenon is still amiss. The computational proof relies on a result proven by Gathmann for the projective plane and extended to arbitrary del Pezzo surfaces by Graber–Hassett. This result provides a correspondence between absolute genus zero Gromov–Witten invariants of the total space of the canonical bundle on S and the relative genus zero Gromov–Witten invariants of maximal tangency of the pair (S, E). Some work has been done towards extending this result to arbitrary dimensions. Consider the open Calabi–Yau $S - E$, for S non-necessarily toric and denote by $M(S)$ the conjectural mirror to $S - E$. The B-model of $M(S)$ is encoded by the derived category of coherent sheaves on $M(S)$. Taking Hochschild cohomology of this category yields the Hochschild cohomology $H(M(S))$ of $M(S)$. Surprisingly, it turns out that as a module over the polynomial ring, $H(M(S))$ is independent of S. Some work has been done towards showing that the periodic cyclic cohomology of $M(S)$ provides a sensible distinction between the different del Pezzo surfaces S.

A paper: *Integrality of relative BPS state counts of toric del Pezzo surfaces*(arXiv:1312.4112) with Tony W. H. Wong and Gjergji Zaimi has been submitted for publication. In this paper, we prove a conjecture by Gross–Pandharipande–Siebert for the case of toric del Pezzo surfaces.

I gave a talk at Geometry and Physics seminar, PIMS, at the University of Alberta, on November 27. Title: Integrality of relative BPS state counts of toric del Pezzo surfaces

Graudate Students

There are two Ph.D. students who took part in the thematic program for six months. They are: Alex Molnar (Queen's) and Yuechen Zhu (Texas at Austin). Here are their activity reports.

Molnar, Alex (Ph.D. student from Queen's University)

During this thematic program we have been investigating more general constructions of Calabi–Yau threefolds, using a technique first used by C. Borcea and C. Voisin. Their idea was to take an elliptic curve E with non-symplectic involution ι along with a $K3$ surface S and non-symplectic involution σ, and consider the variety $X := (E \times S)/(\iota \times \sigma)$, which is usually singular, but admits a crepant resolution, thus gives rise to a Calabi–Yau threefold $\widetilde{X}$.

More generally, one may consider automorphisms of any order on the elliptic curve and the $K3$ surface, and apply this construction to get Calabi–Yau threefolds. Voisin's main result is that the family of threefolds obtained using involutions is closed under mirror symmetry, so our first goal was to search for families with more general automorphisms closed under mirror symmetry. Immediately one finds the family must employ elliptic curves with involutions, and so the classical Borcea–Voisin construction will not admit any similar mirror symmetry relations for threefolds. However, going back to Borcea's original work allows us to construct a new generalization of this construction to get another family of threefolds. We can also construct higher dimensional Calabi–Yau varieties when a crepant resolution exists, e.g., whenever the fixed locus in this construction has codimension at most 3, for example, two $K3$ surfaces with non-symplectic involutions produces a Calabi–Yau fourfold.

Investigating the relationship between zeta functions of Calabi–Yau threefolds and their mirror partners, first conjectured by Candelas et al., we have also been investigating the zeta functions of mirror pairs coming from the family with involutions, as found in the article of Arbebani et al, using both the theory of motives, when applicable, and the more general procedure outlined in the paper of Goto et al. This work is ongoing as part of my PhD research. The material studied here was presented for one of the programs Postdoc seminars, and in Ottawa at the CMS Winter Meeting on December 8th.

Zhu, Yuechen (Ph.D. student from University of Texas at Austin)

I am working on my thesis project. It is about the compactifications of the moduli of abelian varieties. I am using the mirror symmetry to do the compactifications. After talks with many other visitors at the Fields institute, including Fukaya and Gross, the picture of the mirror family has become much clearer now. During my stay at the fields institute, I have finished most of the project, including the construction of families along the boundary. I am now woring on the gluing of the families.

I am also studying wall crossing formulas and wall crossing structures with some other post-doctors at the Fields. I become interested in this topic after Kontsevich and Soibelman's talks during the second workshop: enumerative geometry and Calabi-Yau varieties. I gave a talk "Donaldson-Thomas invariants and wall-crossing formulas" at the Fields institute.

With some post-doctors at the Fields, we have a study seminar on derived algebraic geometry. I am planing to give at least one talk about the deformation theory in derived algebraic geometry next semester at University of Texas at Austin.

Undergraduate Summer Research Students

Espinosa-Lara, Malors (Senior at CIMAT, Mexico), **Molnar, Alexander** (a Ph.D. student at Queen's), **Rabindranath, Ashwash** (Princeton, now a Ph.D. student at Michigan) and **Whang, June Ho (Peter)** (Queen's, now at Ph.D. student at Princeton) were the undergraduate summer research students for the project: *Arithmetic of Calabi–Yau threefolds of Borcea–Voisin type* during July and August, under the supervision of Noriko Yui. Study seminars were organized once a week in August, some of presentations are listed below.

- **Rose, Simon**: *What is orbifold cohomology?*
- **Whang, Jun Ho (Peter**: *L-functions and morphisms.*
- **Molnar, Alexander**: *Generalized Borcea–Voisin construction.*

Besides the above, **Rabindranath, Ashwash, Kanazawa, Atsushi** gave talks at this seminar.

- **Espinosa-Lara, Malors**: *Arithmetic of Calabi–Yau threefolds of Borcea–Voisin type*, Mini-Conference at the Fields Institute, August 21, 2013.

10. Abstracts of Workshop Talks

★Workshop 1: Modular Forms around String Theory, September 16–21, 2013

• Candelas, Phlip: (1) Puzzles to do with the zeta-function for the quintic threefolds, and (2) The lines in the Dwork pencil of quintic threefold

• Clingher, Adrian: Modular forms associated to K3 surfaces endowed with lattice polarizations of high Picard rank

Abstract: I will discuss several cases of lattice polarizations of high Picard rank on a K3 surface. A classification for these objects will be presented in terms of quartic normal forms. Modular forms of appropriate group appear as coefficients of the normal forms.

• Doran, Charles: Families of lattice-polarized K3 surfaces with monodromy

Abstract: We extend the notion of a lattice-polarized K3 surface to families, study the action of monodromy on the Neron-Severi group of the general fiber, and use this to "undo" the Kummer and Shioda-Inose structures in families.This technique sheds important light on the 14 families of Calabi-Yau threefolds with $h_{2,1} = 1$ studied by Doran-Morgan.

This is joint work with Andrew Harder, Andrey Novoseltsev, and Alan Thompson.

•Gao, Peng: Extremal bundles on Calabi–Yau manifolds

Abstract: Motivated by the goal to better understand the implications of stability conditions on numerical invariants, we study explicit constructions of (heterotic string) vector bundles on Calabi-Yau 3 folds. This includes both the monad construction and spectral cover bundles over elliptically fibered CY threefolds. We compare our results with the DRY (Douglas-Reinbacher-Yau) conjecture about generalized Bogomolov-Yau inequalities.

This is a joint work with Y.H. He and S.T. Yau.

•Golyshev, Vasily: Fano threefolds and mirror duality

Abstract: We discuss recent joint work with Coates, Corti, Galkin and Kasprzyk on a mirror link between Fano threefolds and a class of threefolds obtained by generalizing certain modular threefolds.

(His participation was cancelled.)

•Hosono, Shinobu: Mirror symmetry of determinantal quintics

Abstract: I describe mirror symmetry of determinantal quintics defined by generic 5×5 matrices with entries linear in coordinates of $\mathbb{P}^4$. A generic determinantal quintic is singular at 50 nodes, and has a small resolution which is a Calabi-Yau threefold of $h^{1,1} = 2$ and $h^{2,1} = 52$. I will consider the mirror family of this quintic by the orbifold construction starting from a special family of the determinantal quintic. It turns out that the singularities of the special family are similar to the Barth-Nieto quintic, although there are some complications in our case. After making a crepant resolution, we obtain the mirror family, namely we find that the orbifold group G_{org} is trivial in this case. I will also describe Calabi-Yau manifolds related to determinantal quintics which admit free $\mathbb{Z}_2$ quotients.

This is based on the collaborations with Hiromichi Takagi.

•Kelly, Tyler: Berglund–Hübsch–Krawitz mirrors via Shioda maps

Abstract:We will introduce the Shioda map into the Berglund-Hübsch-Krawitz mirror duality proven by Chiodo and Ruan. In particular, we will find a new proof of birationality of BHK mirrors to certain orbifold quotients of hypersurfaces of weighted-projective n-space. We hope to talk about work-in-progress about generalized Shioda maps, BHK mirrors and Picard-Fuchs equations.

•Kudla, Steven: Another product formula for a Borcherds form

Abstract: In his celebrated 1998 Inventiones paper, Borcherds constructed meromorphic automorphic forms $\Psi(F)$ for arithmetic subgroups associated to even integral lattices M of signature $(n, 2)$. The input to his construction is a vector valued weakly holomorphic modular form F of weight $1 - n/2$, and the resulting Borcherds form has an explicit

divisor on the arithmetic quotient $X = \Gamma_M \backslash D$. Most remarkably, in the neighborhood of each cusp (= rational point boundary component), there is a beautiful product formula for $\Psi(F)$, reminiscent of the classical product formula for the Dedekind eta-function. In this lecture, we will describe an analogous product formula for $\Psi(F)$ in the neighborhood of each 1-dimensional rational boundary component. This formula, which, like that of Borcherds, is obtained through the calculation of a regularized theta integral, reveals the behavior of $\Psi(F)$ on a (partial) smooth compactification of X.

•Malmendier, Andreas: Heterotic/F-theory duality and lattice polarized K3 surfaces

Abstract: The heterotic string compactified on T^2 has a large discrete symmetry group $SO(2, 18; \mathbb{Z})$, which acts on the scalars in the theory in a natural way; there have been a number of attempts to construct models in which these scalars are allowed to vary by using $SO(2, 18; \mathbb{Z})$-invariant functions. In our new work (which is joint work with David Morrison), we give a more complete construction of these models in the special cases in which either there are no Wilson lines–and $SO(2, 2; \mathbb{Z})$ symmetry– or there is a single Wilson line–and $SO(2, 3; \mathbb{Z})$ symmetry. In those cases, the modular forms can be analyzed in detail and there turns out to be a precise theory of K3 surfaces with prescribed singularities which corresponds to the structure of the modular forms. This allows us to construct interesting examples of smooth Calabi–Yau threefolds as elliptic fibrations over Hirzebruch surfaces from pencils of irreducible genus-two curves.

•Murthy, Sameer: (1) Quantum black holes, wall crossing, and mock modular forms

Abstract: In the quantum theory of black holes in superstring theory, the physical problem of counting the number of quarter-BPS dyonic states of a given charge has led to the study of Fourier coefficients of certain meromorphic Siegel modular forms and to the question of the modular nature of the corresponding generating functions. These Fourier coefficients have a wall-crossing behavior which seems to destroy modularity. In this talk I shall explain that these generating functions belong to a class of functions called mock modular forms. I shall then discuss some interesting examples that arise from this construction.

This is based on joint work with Atish Dabholkar and Don Zagier.

(2) Mathieu moonshine, mock modular forms and string theory

Abstract: I shall discuss a conjecture of Eguchi, Ooguri and Tachikawa from 2010 that relates the elliptic genus of K3 surfaces and representations of M24, the largest Mathieu group. The generating function of these representations is a mock theta function of weight one-half. After discussing some properties of this function, I shall present a particular appearance of this function in string theory that suggests a construction of a non-trivial infinite-dimensional M24-module.

This is based on joint work with Jeff Harvey.

• Pioline, Boris: Rankin-Selberg methods for closed string amplitudes

Abstract: After integrating over location of vertex operators and supermoduli, scattering amplitudes in closed string theories at genus $h \leq 3$ are expressed as an integral of a Siegel modular form on the fundamental domain of Siegel's upper half plane. I will describe techniques to compute such modular integrals explicitly, by representing the integrand as a Poincaré series and applying the unfolding trick. The focus will be mainly on genus one, but some results on higher genus will be presented.

Based in part on work in collaboration with C. Angelantonj and I. Florakis.

•Rose, Simon: Towards a reduced mirror symmetry for the quartic K3

Abstract: Mirror symmetry in terms of Yukawa couplings for a K3 is relatively trivial, due to the triviality of its Gromov-Witten invariants. Using reduced invariants, however, we can still tease out a lot of enumerative details of these surfaces. As these reduced invariants satisfy the same relations that ordinary invariants do, this raises the natural question: Is there a reduced B-model theory?

In this talk we wil go over our current work on this project, which is joint with Helge Ruddat.

• **Ruan, Yongbin: Mirror symmetry and modular forms, (1) and (2)**

Abstract: Traditionally, we use mirror symmetry to map a difficult problem (A-model) to an easier problem (B-model). Recently, there is a great deal of activities in mathematics to understand the modularity properties of Gromov-Witten theory, a phenomenon suggested by BCOV almost twenty years ago. Mirror symmetry is again used in a crucial way. However, the new usage of mirror does not map a difficult problem to easy problem. Instead, we make both side of mirror symmetry to work together in a deep way. I will explain this interesting phenomenon in the talk. This is a two-parts talk. In the first part, we will give an overview of entire story. In the second part, we will focus on the appearance of quasi-modularity.

•**Wan, Daqing: (1) Rational points on a singular CY hypersurface**

Abstract: The study of higher moments of Kloosterman sums naturally leads to a singular CY hypersurface. In this talk, we explain how to estimate the number of rational points on the singular CY hypersurface via results on the Kloosterman sheaf.

(2) Mirror symmetry for the slope zeta function

Abstract: The slope zeta function is the slope part of the zeta functions of a variety over a finite field. It is an arithmetic object. We expect that the slope zeta function satisfies the expected arithmetic mirror symmetry property for a mirror pair of sufficiently large families of CY hypersurfaces. We shall explain some evidence for this conjecture.

•**Whticher, Ursula: Mirror quartics, discrete symmetries, and the congruent Zeta function**

Abstract: We use Greene-Plesser-Roan and Berglund-Huebsch-Krawitz mirror symmetry to describe the structure of the congruent zeta function for a set of pencils of quartic K3 surfaces which admit discrete group symmetries.

• **Yui, Noriko: Automorphy of Calabi–Yau threefolds of Borcea–Voisin type**

Abstract: Calabi–Yau threefold of Borcea–Voisin type are constructed as the quotients of products of ellptic curves and K3 surfaces by non-symplectic involutions. Resolving singularities, one obtains smooth Calabi–Yau threefolds. We are interested in the modularity (automorphy) of the Galois representations associated to these Calabi–Yau threefolds. We establish the automorphy of some Calabi–Yau threefolds of Borcea–Voisin type.

This is a joint work with Y. Goto and R. Livné.

• **Zagier, Don: (1) Quasimodular forms and holomorphic anomaly equation**

Abstract: Quasimodular forms are a special class of holomorphic functions that are nearly modular and become modular after the addition of a suitable non-holomorphic correction term. They are thus similar to, but much simpler than, mock modular forms. They occur in mirror symmetry in several ways, one of these being the so-called "holomorphic anomaly equation" which describes a sequence of quasimodular forms with the non-modularity of each form being defined inductively in terms of its predecessors. We will describe how this works and how one can understand the structure of the HAE in terms of deformations of power series solutions to linear differential equations and "bimodular forms", which are yet another type of nearly modular object.

This is joint work with Jan Stienstra.

(2) Some number theory coming from string amplitude calculations

Abstract: Calculations of amplitudes in string theory lead in a natural way to multiple zeta values at the "tree" (genus 0) level and to interesting modular functions at the "1-loop" (genus 1) level. The talk will discuss various calculations related to this that seem to have interesting arithmetic aspects, including certain very specific rational linear combinations of multiple zeta values that rather mysteriously occur in both the tree and 1-loop level calculations, and also some proven and conjectural identities for special values of Kronecker-Eisenstein type lattice sums.

• **Zhou, Jie: Gromov-Witten invariants and modular forms**

Abstract: In this talk we shall solve the topological string amplitudes in termsof quasi modular forms for some noncompact CY 3–folds.

After a quick review of the polynomial recursion technique which is used to solve the BCOV holomorphic anomaly equations, we will construct the special polynomial ring which has a nice grading and show that topological string amplitudes are polynomials of these generators. For the cases in which the moduli space of complex structures could be identified with a modular curve, this ring is exactly the differential ring of quasi modular forms constructed out of periods. Moreover, the Fricke involution serves as a duality relating the amplitudes at the large complex structure limit and the conifold point. Combing the polynomial recursion technique and the duality, we will then be able to express the topological string amplitudes in terms of quasi modular forms. For other cases, the special polynomial ring gives a generalization of the ring of quasi modular forms without knowing much about the arithmetic properties of the moduli space.

★Workshop 2: Enumerative Geometry and Calabi–Yau Varieties: October 15–19, 2013

• Abouzaid, Mohammed: Formality of Fukaya categories from disc counts

Abstract: One of the main problems in computing Fukaya categories is to understand the underlying A-infinity structure even for simple and explicitly constructed Lagrangians. I will explain how one can use counts of holomorphic discs to prove the formality of certain (subcategories of) Fukaya categories, focusing on the example of the Milnor surfaces of type A.

This is joint work with I. Smith.

• Abramovich, Dan: The decomposition formula for logarithmic Gromov-Witten invariants

Abstract: This is joint work of Qile Chen, Mark Gross, Bernd Siebert and me.

A central aim of logarithmic Gromov–Witen theory is to find general formulas relating usual Gromov–Witten invariants of a smooth variety X with appropriate invariants of simpler varieties which appear as components of a degeneration of X. The first step is the decomposition formula, which breaks apart invariants of the singular fiber in combinatorial terms determined by tropical curves or graphs. I will describe our work on the decomposition formula, with examples (at least one example).

•Brav, Chris: Hamiltonian local models for symplectic derived stacks

Abstract: We show that a derived stack with symplectic form of negative degree can be locally described in terms of generalised Darboux coordinates and a Hamiltonian cohomological vector field. As a consequence we see that the classical moduli stack of vector bundles on a Calabi–Yau threefold admits an atlas consisting of critical loci of regular functions on smooth varieties. If time permits, we discuss applications to the categorification of Donaldson–Thomas theory.

This is joint work with subsets of Ben-Bassat, Bussi, Dupont, Joyce, and Szendroi.

•Bryan, Jim: π-stable pairs and the crepant resolution conjecture in Donaldson-Thomas theory.

Abstract: We construct curve counting invariants for a Calabi–Yau threefold Y equipped with a dominant birational morphism $\pi : Y \to X$. Our invariants generalize the stable pair invariants of Pandharipande and Thomas which occur for the case when $\pi : Y \to Y$ is the identity. In the case where $\pi : Y \to X$ is a semi-small crepant resolution, we prove a PT/DT - type formula relating the partition function of our invariants to the Donaldson-Thomas partition function. In the case where X is the coarse space of a Calabi–Yau orbifold, our partition function is equal to the Pandharipande–Thomas partition function of the orbifold. Our methods include defining a new notion of stability for sheaves which depends on the morphism π. Our notion generalizes slope stability which is recovered in the case where π is the identity on Y.

•Chen, Qile: Very free curves on Fano complete intersections

Abstract: The theory of stable log maps are developed for studying the degeneration of Gromov–Witten invariants. In this talk, I will introduce another interesting application of stable log maps to classical birational geometry — we construct very free curves on Fano complete intersections in projective spaces over an algebraically closed field of arbitrary characteristics.

This is a joint work with Yi Zhu.

•Cooper, Yaim: The geometry of stable quotient spaces in genus one

Abstract: Stable quotient spaces provide an alternative to stable maps for compactifying spaces of maps. In this talk I will discuss spaces of stable quotients which compactify the space of degree d maps of genus 1 curves to $\mathbb{P}^n$. I will describe what is known about the geometry of these spaces. I will also discuss the relationship between these spaces and the corresponding spaces of stable maps from the perspective of the minimal model program.

•Costello, Kevin: Quantization of BCOV theory on Calabi–Yau manifolds

Abstract: I'll discuss some aspects of work in progress with Si Li on quantization of open and closed BCOV theory on Calabi-Yau manifolds. This gives a new formulation of the B-model which is local on the Calabi-Yau. If time permits, I'll discuss some calculations in both the open and closed versions of this theory.

•Diaconescu, Duiliu: Parabolic refined invariants and Macdonald polynomials

Abstract: A string theoretic derivation is given for the conjecture of Hausel, Letellier and Rodriguez-Villegas on the cohomology of character varieties with marked points. Their formula is identified with a refined BPS expansion in the stable pair theory of a local root stack. Morever, Haiman's geometric constyruction for Macdonald polynomials is shown to emerge naturally in the context of geometric engineering.

•Filipinni, Sara: Refined curve counting and wall-crossing

Abstract: The tropical vertex group of Kontsevich and Soibelman is generated by formal symplectomorphisms of the 2-dimensional algebraic torus. It plays a role in many problems in algebraic geometry and mathematical physics. Based on the tropical vertex group, Gross, Pandharipande and Siebert introduced an interesting Gromov–Witten theory on weighted projective planes which admits a very special expansion in terms of tropical counts. I will describe a refinement or "q-deformation" of this expansion, motivated by wall-crossing ideas, using Block–Goettsche invariants. This leads naturally to the definition of a class of putative q-deformed curve counts. We prove that this coincides with another natural q-deformation, provided by a result of Reineke and Weist in the context of quiver representations, when the latter is well defined.

Joint work with Jacopo Stoppa.

•Fukaya, Kenji: Perturvation of constant maps, String topology and Perturbative Chern-Simons Theory

Abstract: In this talk I will explain the way to obtain a solution of certain master equation onthe cyclic bar complex of the de-Rhamcohomology. This solution is a constant map part of Lagrangian Floer theory and is related to the two stories in the title. Something new in this talk, which I will explain, is the way how to do it without using pseudoholomorphic curvein the cotangent bundle. So everything works in the story of finite dimensional spaces. However 'virtual technique' is used much.

•Gross, Mark: Introduction to Logarithmic Gromov–Witten invariants

Abstract: Log Gromov–Witten invariants are a generalization of relative Gromov–Witten invariants. They can be used to define the notion of curve counts with specified tangencies along normal crossings divisors, or curve counts in normal crossings target spaces. I will outline the basic definitions of these invariants as developed by myself and Siebert, on the one hand, and Abramovich and Chen, on the other.

•Kontsevich, Maxim: (1) What is tropical mathematics?

Abstract: In tropical mathematics the usual laws of algebra are changed, the subtraction is forbidden, the division is always permitted, and 1+1 is equal to 1. Analogs of usual geometric shapes like lines, circles etc. are replaced by

new figures composed of pieces of lines. I will try to explain basics of tropical algebra and geometry, its relation with more traditional domains, and its role in mirror symmetry which is a remarkable duality originally discovered in string theory about 20 years ago.

(2) Quivers, cluster varieties and integrable systems

Abstract: I'll describe a new approach to cluster varieties and mutations based on scattering diagrams and wall-crossing formalism. The central role here is played by certain canonical transformation (formal change of coordinates) associated with arbitrary quiver. Also, a complex algebraic integrable system under some mild conditions produces a quiver, and the associated canonical transformation is a birational map.

(3): Fukaya category meets Bridgeland stability

Abstract: Bridgeland's notion of stability in triangulated categories is believed to be a mathematical encoding of D-branes in string theory. I'll argue (using physics picture) that partially degenerating categories with stability should be described as a mixture between symplectic geometry and pure algebra. Spectral networks of Gaiotto, Moore and Neitzke appear as an example.

•Ruan, Yongbin: A mathematics theory of gauged linear sigma model

Abstract: Several years ago, we (Fan, Jarvis and myself) developed a theory for so called Landau-Ginzburg model. It has a variety of applications in integrable hierarchy, LG/CY correspondence and modularity. LG-model is a limit of so called gauged linear sigma model. In the talk, I will discuss a construction to generalize our "classical" theory to the general situation of gauged linear sigma model. Some potential applications will be discussed.

• Ruddat, Helge: Speculations on Mirror Symmetry for Riemann surfaces

Abstract: There has been quite some evidence that some form of mirror symmetry is valid for curves of higher genus. In known constructions, the dual geometry is derived from a higher-dimensional Landau–Ginzburg model. We present some ideas of how an intrinsic form of the mirror construction could be fomulated.

• Soibelman, Yan: 3-dimensional Calabi-Yau manifolds and Hitchin integrable systems

Abstract: I am going to discuss the relationship between two topics mentioned in the title from the point of view of theory of Donaldson-Thomas invariants and wall-crossing formulas developed by Kontsevich and myself.

• Tseng, Hsian-Hua: Mirror theorem, Seidel representation, and holomorphic disks

Abstract: The quantum cohomology ring $QH^*(X)$ of a projective toric manifold X can be computed in several ways. A presentation of $QH^*(X)$ can be derived from the toric mirror theorem of Givental, Lian-Liu-Yau, and Iritani. McDuff-Tolman use d Seidel representations to derive a presentation of $QH^*(X)$. More recently, Fukaya-Oh-Ohta-Ono showed that $QH^*(X)$ is isomorphic to the Jacobian ring of the Lagrangian Floer superpotential of X, which is defined in terms of counting of holomorphic disks in X. The purpose of this talk is to explain the geometric reason underlying the equivalence of these three seemingly very different approaches, when X is semi-Fano.

•Zaslow, Eric: Legendrian knots and constructible sheaves

Abstract: Given a Legendrian knot, we construct a category, invariant under Legendrian isotopies up to equivalence. Rank-one objects of our category play a special role. On the one hand, they define a subcategory which we conjecture to be equivalent to the bilinearized Legendrian contact homology of the knot. On the other hand, the moduli of these objects is an interesting space which, for positive braid closures, enables one to recover the Khovanov–Rozansky categorified invariant of the topological type of the knot.

I will try to explain all this by working through simple examples.

This work is joint with Vivek Shende and David Treumann

• Zinger, Alekesy: Mirror Symmetry for Stable Quotients Invariants

Abstract: I will describe a mirror formula for the direct analogue of Givental's J-function in the SQ theory. It is remarkably similar to the mirror formula in the Gromov–Witten theory, but the former does not involve a change of variables. This suggests that the mirror map relating the GW-invariants to the B-model of the mirror is more reflective

of the choice of curve counting theory on the A side than of mirror symmetry. The proof of the mirror formula in the Fano case is as in the GW–theory. On the other hand, the proof in the Calabi–Yau case consists of showing that it is a consequence of the Fano case.

This is joint work with Y. Cooper.

★Workshop 4: Hodge Theory in String Theory, November 18–22, 2013

•Ballard, Matt: Griffiths' residue theorem via Landau-Ginzburg models

Abstract: I will discuss how Griffiths' residue theorem can be understood from the sigma-model/LG-model correspondence. This is joint work with David Favero (Alberta) and Ludmil Katzarkov (Miami/Vienna).

•Charles, Francois: Families of rational curves on holomorphic symplectic fourfolds

Abstract: Families of rational curves on holomorphic symplectic fourfolds It has been shown by Bogomolov–Mumford and Mori–Mukai that projective K3 surfaces contain ample rational curves. We construct uniruled divisors and rational surfaces on every projective irreducible holomorphic symplectic fourfold of $K3^{[2]}$ type. As a consequence, we construct a canonical zero-cycle á la Beauville–Voisin on any such fourfold.

This is joint work with Gianluca Pacienza.

•Dettweiler, Michael: Construction of differential equations of Calabi-Yau type and Hodge theory

Abstract: In the work of Reiter and Bogner, many differential equations of Calabi-Yau type are constructed using additive and multiplicative convolution (= Hadamard product). We recall their work and describe an algorithm, developed jointly by Claude Sabbah and the speaker, on how to determine the basic underlying local and global Hodge numerical data for the variations of Hodge structures underlying these differential equations of Calabi-Yau type.

•Doran, Charles: Landau-Ginzburg models of Fano threefolds and moduli spaces of K3 surfaces

Abstract: To a Fano threefold equipped with a complexified Kaehler class, we may associate a Landau-Ginzburg potential whose fibers over the complex line are K3 surfaces. In this talk, wewill illustrate, via examples, howthe birational geometry of Fano threefolds is captured by the geometry of special families of curves in themoduli spaces of lattice polarized K3 surfaces whichareDolgachev-Nikulin mirror to the anticanonical K3 surfaces in the Fano threefold. We will also discuss anapplication to the geometric construction ofcertainCalabi-Yau threefolds whose moduli space isthe thrice-punctured sphere.

•Garbagnati, Alice: Calabi–Yau threefolds of Borcea–Voisin type

Abstract: The Borcea-Voisin construction is a way to produce Calabi–Yau 3-folds as crepant resolutions of quotients $(S\times E)/(\mathbb{Z}/2\mathbb{Z})$ where S is a K3 surface, E is an elliptic curve and $\mathbb{Z}/2\mathbb{Z}$ acts diagonally on $S\times E$. Several generalizations of this construction were considered in the last years. Here we consider Calabi–Yau 3-folds which are crepant resolutions of quotients $(S\times E)/\mathbb{Z}/n\mathbb{Z}$ where $n = 2, 3, 4, 6$ and, as before, S is a K3, E is an elliptic curve and $\mathbb{Z}/n\mathbb{Z}$ acts diagonally on $S \times E$. This imposes restrictions both on the elliptic curve E and on the K3 surface S. We study the K3 surfaces involved in this construction, we describe explicitly certain crepant resolutions of $(S \times E)/(\mathbb{Z}/n\mathbb{Z})$, we compute the Hodge numbers of the Calabi–Yau obtained. Some of the Calabi–Yau constructed are "new" and some of them lie in families without maximal unipotent monodromy. In certain cases one proves that the variation of the Hodge structures of the families of Calabi–Yau considered is essentially the variation of the Hodge structures of families of curves. Moreover, by construction, the Calabi–Yau 3-folds obtained admit an (almost) elliptic fibration which is isotrivial. We describe this fibration and give a Weierstrass equation in certain cases. Some of the results presented are obtained in collaboration with Bert van Geemen, otherswith Andrea Cattaneo.

•Katzarkov, Ludmil: Mixed Hodge Structures and phantoms

Abstract: On this talk we will look at some classical examples from the point of view of category theory and Homological Mirror Symmetry.

• Matt Kerr: Algebraic cycles and local quantum cohomology

Abstract: In this talk, based on joint work with C. Doran, I will describe some possible A-model interpretations of variations of mixed Hodge structure arising in local and open mirror symmetry. The discussion will focus on examples arising in the work of Hosono and Morrison/Walcher, and will highlight in each case interesting questions about homological mirrors of cycle-class maps.

•Malmendier, Andreas: Multi-parameter families of K3 surfaces from Seiberg-Witten curves and hypergeometric functions

Abstract: In my talk I will generalize Sen's procedure by constructing all 2-parameter families of lattice-polarized K3 surfaces that can be obtained from extremal rational elliptic surfaces through a quadratic twist. I will show that for all of these families the Picard-Fuchs system governing the K3-periods are obtained by an integral transform of a differential equation of hypergeometric or Heun type, and that in fact the K3-periods have an interpretation as modular forms and solutions to a GKZ system. If time permits I will also explain how further generalization of this procedure naturally leads to K3 surfaces admitting double covers onto P2 branched along a plane sextic curve.

(This is joint work with Chuck Doran, University of Alberta)

•Morrison, David: (1) Variations of Hodge structure, Gromov-Witten invariants, and the Gamma class

Abstract: The original mirror symmetry predictions of Gromov-Witten invariants of Calabi-Yau threefolds relied heavily on the behavior of a degenerating variation of Hodge structure near the boundary of Calabi–Yau moduli space. This led to a definition in the early 1990's of the "A-variation of Hodge structure": a degenerating variation of Hodge structure directly constructed from the Gromov-Witten invariants themselves.

Recently, there have been advances in the physical study of the "A-model" (the physical theory leading to Gromov-Witten invariants), which have revealed that one aspect of the original definition of A-VHS needs clarification and modification. The modification involves the Gamma class, a characteristic class closely related to the Gamma function.

We will explain this modification, and discuss some interesting examples.

(2) Clemens–Schmid and mixed Hodge structures in string theory

Abstract: The theory of mixed Hodge structures and the Clemens–Schmid exact sequence have seen several recent applications in string theory, which I shall survey.

• Movassati, Hossein: A common framework for automorphic forms and topological partition functions

Abstract: Classical modular forms and in general automorphic forms enjoy q-expansions with fruitful applications in different branches of mathematics. From another side we have q-expansions coming from the B-model computations of mirror symmetry which, in general, are believed to be new functions. In this talk I will present a common algebro-geometric framework for all these q-expansions. This is based on the moduli of varieties with a fixed topological data and enhanced with a basis of the algebraic de Rham cohomology, compatible with the Hodge filtration and with a constant intersection matrix. In our way, we will also enlarge the algebra of automorphic forms to a bigger algebra which is closed under canonical derivations. I will mainly discuss three examples: 1. Elliptic curves and classical modular forms, 2. Principally polarized abelian varieties, lattice polarized K3 surfaces and Siegel modular forms 3. Mirror quintic Calabi-Yau varieties, Yukawa coupling and topological partition functions.

•Mustata, Anca: The Dwork pencil of quintic threefolds

Abstract: In this talk we will review existing results and open questions related to Dwork pencil of quintic threefolds and its quotient, the mirror quintic. This family of quintics has proven a particularly fertile testing ground from the beginnings of mirror symmetry.

•Pearlstein, Greg: Naive limits of Hodge structure

Abstract: Traditionally, one computes the asymptotic periods of a variation of Hodge structure with respect to the canonical extension. For Hodge structures of high level, there is also interesting information in the naive limit filtration. This talk is based on joint work with M. Kerr.

• Peters, Chris: Two isomorphic classical domains and related geometric moduli spaces

Abstract: The classical isomorphism of simple Lie groups

$$\mathrm{U}(2,2)/\text{center} \simeq \mathrm{O}(2,4)/\text{center}$$

leads to a biholomorphic isomorphism between the corresponding homogeneous domains

$$\mathbf{H_2} = \mathrm{U}(2,2)/\mathrm{U}(2)\times\mathrm{U}(2) \simeq D_4 = \mathrm{O}(2,4)/\mathrm{O}(2)\times\mathrm{O}(4).$$

The domains have complex dimension 4. The first, $\mathbf{H_2}$ parametrizes **principally polarized Abelian 4-folds** with an extra involution of order 4 and the second, D_4 parametrizes **K3-surfaces** that are double covers of the plane branched in 6 lines in general position. The isomorphism can be explained using Hodge theory. To obtain the true moduli spaces one divides out by the appropriate discrete groups. Certain divisors of these moduli spaces studied previously on the Abelian 4-fold side have explicit descriptions on the K3-side.

Finally, there is an intriguing relation with the Kuga-Satake correspondence associated to "generic" points in these moduli spaces as well as their divisors.

This is a report of recent joint work with Giuseppe Lombardo and Matthias Schütt.

•Sacca, Giulia: Calabi-Yau manifolds and relative Jacobians of linear systems on surfaces with trivial Kodaira dimension

Abstract: Let X be a surface whose canonical bundle is (non trivial) torsion of degree 2, and let $|C|$ be a linear system on X. I will show how the relative compactified Jacobian of $|C|$ is an (odd dimensional) Calabi-Yau manifold. This result is conditional to a very natural assumption that holds for low values of the genus of the linear system, and that is expected to hold in general. After discussing this assumption, I will focus about some aspects of the topology of these relative compactified Jacobians.

• Usui, Sampei: Studies of closed/open mirror symmetry for quintic threefolds through log mixed Hodge theory

Abstract: We try to understand closed and open mirror symmetry for quintic threefolds in the framework of the fundamental diagram, obtained by the joint work of Kato, Nakayama, and Usui, which relates various compactifications of classifying space of mixed Hodge structures.

• Voisin, Claire: (1) The canonical 0-cycle of a K3 surface

Abstract: Beauville and I proved that an algebraic K3 surface S has a 0-cycle which is canonically defined modulo rational equivalence, and has the property that the intersection of any two divisors on S is proportional to it.

I will review a number of properties of this cycle, some of which have been discovered by Huybrechts in his study of spherical objects in the derived category of S.

(2) On the Chow ring of Calabi–Yau manifolds

Abstract: I will describe generalizations, some of which are conjectural, of the canonical ring of a K3 surface to higher dimensional hyper-Kaehler manifolds or to more general Calabi-Yau manifolds. For Calabi-Yau hypersurfaces X, for example, I show that the intersection of any two cycles of complementary nonzero dimension is proportional to the canonical 0-cycle (the intersection of a line with X). In the hyper-Kaehler case, the canonical ring is generated by the divisor classes and the Chern classes of the tangent bundle and it is conjectured that the cycle class map is injective on it.

(3) Decomposition of the small diagonal and the topology of families

Abstract: The results on the Chow ring of K3 surfaces and of Calabi-Yau hypersurfaces are obtained by decomposing the small diagonal in the Chow group of the triple product X^3. In the case of a K3 surface, this decomposition has the following consequence on families $f : S \to B$ of projective K3 surfaces parametrized by a quasi-projective basis B: Up to shrinking B to a dense Zariski open set, there is a multiplicative decomposition of Rf_*Q, that is a decomposition as the direct sum of its cohomology sheaves, which is compatible with cup-product on both sides. This is reminiscent to what happens with families of abelian varieties, and is very restrictive on the topology of the family.

(4) Varieties of power sums and divisors on the moduli space of cubic fourfolds

Abstract: This is a joint work with K. Ranestad. To a cubic fourfold X is associated its variety of lines, which is known by Beauville and Donagi to be a hyper-Khler fourfold whose Hodge structure on degree 2 cohomology is isomorphic to the Hodge structure on degree 4 cohomology of X. Iliev and Ranestad associated to X another hyper-Khler fourfold, constructed as the variety of powersums of X. We show that for this second hyper-Khler fourfold, there is (for general X) no non-trivial morphism of Hodge structures from the Hodge structure on its degree 2 cohomology to the Hodge structure on degree 4 cohomology of X.

• **Walcher, Johannes: On 2-functions and their framing**

Abstract: 2-functions are defined by an integrability condition with respect to the action of the Frobenius endomorphism on formal power series with algebraic coefficients. They play a role in (open string) mirror symmetry, and perhaps in other contexts as well. Among their non-trivial elementary properties is the stability under the framing transformation, which can be proven in several different ways. Based on joint work with A. Schwarz and V. Vologodsky

•**Zuo, Kang: On Shimura curves in Torelli locus of hyperelliptic curves**

Abstract: In my talk I shall report my recent joint work with Xin LU We show that there do not exist Shimura curves contained in generically in the Torelli locus of hyperelliptic curves of genus $g > 7$. We also present examples of such Shimura curves for $g = 3$ or 4.

10. Schedules of Concentrated Graduate Courses, and Workshops

★ The Introductory Workshop: August 26–30, 2013 at Bahen Building Room 1180

WORKSHOP SCHEDULE

The duration of a lecture is one hour followed by 10 minutes question period.

	Aug. 26	Aug. 27	Aug. 28	Aug. 29	Aug. 30
9:30–10:30	Hulek	Walcher	Whitcher	Doran	Doran
11:00–12:00	Gross	Gross	Ruddat	Yui	Yui
14:00–15:00	Walcher	Hulek	Laza	Laza	Thomas
15:30–16.30	Whitcher	Siebert	Gross	Siebert	Filippini

★ The Concentrated Graduate Course for Workshop 1: Modular Forms Around String Theory, September 9–13, 2013

SCHEDULE FOR THE CONCENTRATED GRADUATE COURSES

	Sept. 9	Sept. 10	Sept. 11	Sept. 12	Sept. 13
10:00–11:00	Rose	Rose	Zhou	Doran	Harder
11:15–12:15	Perunicic	Zhou	Perunicic	Thompson	Clingher
Afternoon	Discussion	Discussion	Discussion	Discussion	Discussion

★ Workshop on Modular Forms around String Theory: September 16–20, 2013

WORKSHOP SCHEDULE

The duration of a lecture is one hour followed by 10 minutes question period.

	Sept. 16	Sept. 17	Sept. 18	Sept. 19	Sept. 20
9:00–10:00	Clingher	Kelly	Wan	Kudla	Yui
10:30–11:30	Ruan	Candelas	Pioline	Gao	Hosono
11:30–12:30	Doran	Ruan	Zhou	Zagier	Candelas
14:00–15:00	Malmendier	Zagier	Free	Murthy	Rose
15:30–16.30	Whitcher	Murthy	Free	Wan	
17:00–19:00		Reception			

★ The Concentrated Graduate Courses for Workshop 2: Enumerative Geometry and Calabi–Yau Varieties, and Workshop 3: Physics around Mirror Symmetry: October 7–11, 2013

SCHEDULE FOR THE CONCENTRATED GRADUATE COURSES

	Oct. 7	Oct. 8	Oct. 9	Oct. 10	Oct. 11
10:00–11:00	Rose	van Garrel (2)	van Garrel (3)	Filippini (1)	Quigley (2)
11:15–12:15	van Garrel (1)	Overholser (1)	Overholser (2)	Priddis (1)	Priddis (2)
2:00-3:00	Ruddat (1)	Ruddat (2)	Man-Wai	Quigley (1)	Filippini (2)

★Workshop 2: Enumerative Geometry and Calabi–Yau Varieties: October 15–19, 2013

WORKSHOP SCHEDULE

The duration of a lecture is one hour followed by 10 minutes question period.

	Oct. 15	Oct. 16	Oct. 17	Oct. 18	Oct. 19
9:30–10:30	Gross	Abramovich	Chen	Ruan	Diaconescu
11:00–12:00	Costello	Soibelman	Bryan	Filipinni	Zaslow
14:00–15:00	Abouzaid	Tseng	Fukaya	Cooper	Brav
15:30–16:30	DLS (I) Kontsevich	DLS (II) Kontsevich	DLS (III) Kontsevich	Zinger	Ruddat
16:30–18:30	DLS Reception				

★ Workshop 3: Physics around Mirror Symmetry, October 21–25, 2013 at Perimeter Institute

WORKSHOP SCHEDULE

The duration of a lecture is one hour followed by 10 minutes question period.

	Nov. 21	Nov. 22	Nov. 23	Nov. 24	Nov. 25
10:00–11:00	Kachru	Okuda	Soibelman	Bouchard	Karigiannis
11:00–12:00	Melnikov	Hori	Klemm	Couso	Walcher
14:30–15:30	Diaconescu	Gaiotto	Gualtieri	Favero	
16:00–17:00		Borot	Gualtieri	Quigley	

★ The Concentrated Graduate Course for Workshop 4: Hodge Theory in String Theory, November 18–22, 2013

SCHEDULE FOR THE CONCENTRATED GRADUATE COURSES

	Nov. 11	Nov. 12	Nov. 13	Nov. 14	Nov. 15
Location	Library	230	230	210/230	??
10:00–11:00	Filippini	Garcia–Raboso	Radu	Radu	Harder
11:15–12:15	Thompson	Rayan	Schuett	Peters	Peters
2:00–3:00	Ruddat	Schuett	Kerr	Kerr	Kerr
3:30–4:30			CLS Voisin	CLS Voisin	
4:30–6:30			CLS Reception		

★ Workshop on Hodge Theory in String Theory: November 18–22, 2013

WORKSHOP SCHEDULE

The duration of a lecture is one hour followed by 10 minutes question period.

	Nov. 18	Nov. 19	Nov. 20	Nov. 21	Nov. 22
9:30–10.30	Kerr	Sacca	Walcher	Usui	Malmendier
11:00–12:00	Movasati	Doran	Mustata	Garbagnati	Morrison
14:00–15:00	Katzarkov	Dettweiler	Ballard	Peters	Pearlstein
15:30–16:30	CLS (III) Voisin	Morrison	Zuo	Voisin	Charles
17:00–19:00	CLS Reception				

11. Lists of Participants

★ SUMMER SCHOOL, July and August 2013

The total number of registered participants was **20**.

- **Amir-Khosravi, Zavosh**, University of Toronto
- **Ceballos, Cesar**, York University
- **Cheung, Man-Wai**, University of California San Diego
- **Filippini, Sara**, Fields Institute
- **Fisher, Jonathan**, University of Toronto
- **Garcia-Raboso, Alberto**, University of Toronto
- **Hulek, Klaus**, University of Hannover
- **Kanazawa, Atsushi**, University of British Columbia
- **Molnar, Alexander**, Queen's University
- **Overholse, Douglas Peter**, Fields Institute
- **Perunicic, Andrija**, Fields Institute
- **Rayan, Steve**, University of Toronto
- **Rose, Simon**, Fields Institute
- **Ruddat, Helge**, Fields Institute
- **Soloviev, Fedor**, University of Toronto
- **Thompson, Alan**, Fields Institute
- **van Garrel, Michel**, Fields Institute
- **Whang, Jun Ho (Peter)**, Queen's University/Princeton University
- **Yui, Noriko**, Queen's University/Fields Institute
- **Zhu, Yuecheng**, University of Texas at Austin

★ INTRODUCTORY WORKSHOP, August 26–30, 2013 at Bahen Building Room 1180

The total number of registered participants was **32**.

- **Ceballos, Cesar**, York University
- **Cheung, Man-Wai**, University of California San Diego
- **Filippini, Sara**, Fields Institute
- **Gao, Peng**, Stony Brook University
- **Garcia-Raboso, Alberto**, University of Toronto
- **Gross, Mark**, University of California San Diego
- **Gualtieri, Marco**, University of Toronto
- **Harder, Andrew**, University of Alberta
- **Hulek, Klaus**, University of Hannover
- **Kanazawa, Atsushi**, University of British Columbia
- **Lamy-Poirier, Joel**, Perimeter Institute for Theoretical Physics
- **Laza, Radu**, Stony Brook University
- **Livinskyi, Ivan**, University of Toronto
- **Luo, Tie**, National Science Foundation (NSF)
- **Matviichuk, Mykola**, University of Toronto
- **Molnar, Alexander**, Queen's University
- **Overholser, Douglas (Peter)**, Fields Institute
- **Perunicic, Andrija**, Fields Institute
- **Rayan, Steve**, University of Toronto
- **Rose, Simon**, Fields Institute
- **Ruddat, Helge**, Fields Institute
- **Selmani, Sam**, McGill University
- **Serajelahi, Baran**, University of Western Ontario
- **Soloviev, Fedor**, University of Toronto
- **Thomas, Hugh**, University of New Brunswick

- **Thompson, Alan**, Fields Institute
- **van Garrl, Michel**, Fields Institute
- **Walcher, Johannes**, McGill University
- **Whitcher, Usula**, University of Wisconsin-Eau Claire
- **Yui, Noriko**, Queen's University/Fields Institute
- **Zhu, Yuecheng**, University of Texas at Austin
- **Shu, Zhifei**, University of Toronto

★ The Concentrated Graduate Course for Workshop 1, September 9–13, 2013

The total number of registered participants was **21**.

- **Ceballos, Cesar**, York University
- **Clingher, Adrian**, University of Missouri St Louis
- **Fei, Teng**, MIT
- **Filippini, Sara**, Fields Institute
- **Gao, Peng**, Stony Brook University
- **Garcia-Raboso, Alberto**, University of Toronto
- **Harder, Andrew**, University of Alberta
- **Kelly, Tyler**, University of Pennsylvania
- **Molnar, Alexander**, Queen's University
- **Overholser, Douglas (Peter)**, Fields Institute
- **Perunicic, Andrija**, Fields Institute
- **Rayan, Steve**, University of Toronto
- **Rose, Simon**, Fields Institute
- **Ruddat, Helge**, Fields Institute
- **Soloviev, Fedor**, University of Toronto

- **Thompson, Alan**, Fields Institute
- **van Garrel, Michel**, Fields Institute
- **Whitcher, Usula**, University of Wisconsin–Eau Claire
- **Yui, Noriko**, Queen's University/Fields Institute
- **Zhou, Jie**, Harvard University
- **Zhu, Yuecheng**, University of Texas at Austin

★ WORKSHOP 1: MODULAR FORMS AROUND STRING THEORY, September 16–20, 2013 at Fields Institute

The total number of registered participants was **43**.

- **Amir-Khosravi, Zavosh**, University of Toronto
- **Barron, Tatyana**, University of Western Ontario
- **Candelas, Philip**, University of Oxford
- **Caviedes Castro, Alexander**, University of Toronto
- **Ceballos, Cesar**, York University
- **Clingher, Adrian**, University of Missouri-St. Louis
- **Fei, Teng**, Massachusetts Institute of Technology (MIT)
- **Filippini, Sara**, Fields Institute
- **Gao, Peng**, Stony Brook University
- **Garcia-Raboso, Alberto**, University of Toronto
- **Gonzalez-Dorrego, Maria R**, University of Toronto
- **Goto, Yasuhiro**, Hokkaido University of Education
- **Gualtieri, Marco**, University of Toronto
- **Harder, Andrew**, University of Alberta
- **Hosono, Shinobu**, University of Tokyo
- **Kelly, Tyler**, University of Pennsylvania

- **Koroteev, Peter**, Perimeter Institute for Theoretical Physics
- **Kudla, Stephen**, University of Toronto
- **Li, Yingkun**, University of California Los Angeles
- **Luk, Kevin**, University of Toronto
- **Malmendier, Andreas**, Colby College
- **Molnar, Alexander**, Queen's University
- **Murthy, Sameer**, Kings College London
- **Overholser, Douglas (Peter)**, Fields Institute
- **Perunicic, Andrija**, Fields Institute
- **Pioline, Boris**, CERN/Jussieu
- **Rahmati, Mohammad Reza**, CIMAT
- **Rayan, Steve**, University of Toronto
- **Rose, Simon**, Fields Institute
- **Ruan, Yongbin**, University of Michigan
- **Ruddat, Helge**, Fields Institute
- **Schaug, Andrew**, University of Michigan
- **Selmani, Sam**, McGill University
- **Silversmith, Robert**, University of Michigan
- **Soloviev, Fedor**, University of Toronto
- **Thompson, Alan**, Fields Institute
- **van Garrel, Michel**, Fields Institute
- **Wan, Daqing**, University of California Irvine
- **Whitcher, Usula**, University of Wisconsin-Eau Claire
- **Yui, Noriko**, Queen's University/Fields Institute
- **Zagier, Don**, Max-Planck-Institut fÚr Mathematik Bonn
- **Zhou, Jie**, Harvard University
- **Zhu, Yuecheng**, University of Texas at Austin

★ The Concentrated Graduate Courses for Workshop 2 and Workshop 3, October 7–11, 2013

The total number of registered participants was **28**.

- **Amir-Khosravi, Zavosh**, University of Toronto
- **Ceballos, Cesar**, York University
- **Delieu, Thomas**, Université Paul Sabatier
- **Faber, Eleonore**, University of Toronto
- **Filippini, Sara**, Fields Institute
- **Garcia-Raboso, Alberto**, University of Toronto
- **Gonzalez-Dorrego, Maria R**, University of Toronto
- **Gualtieri, Marco**, University of Toronto
- **Li-Bland, David**, Berkeley
- **Luk, Kevin**, University of Toronto
- **Marcus, Steffen**, University of Utah
- **Molnar, Alexander**, Queen's University
- **Overholse, Douglas (Peter)**, Fields Institute
- **Perunicic, Andrija**, Fields Institute
- **Priddis, Nathan**, University of Michigan
- **Prym Brent**, McGill University
- **Quigley, Callum**, University of Alberta
- **Rayan, Steve**, University of Toronto
- **Rose, Simon**, Fields Institute
- **Ruddat, Helge**, Fields Institute
- **Schaug, Andrew**, University of Michigan
- **Selmani, Sam**, McGill University
- **Soloview, Fedor**, Fields Institute
- **Thompson, Alan**, Fields Institute
- **van Garrel, Michel**, Fields Institute

- **Wang, Yicao**, University of Toronto
- **Yui, Noriko**, Queen's University/Fields Institute
- **Zhu, Yuecheng**, University of Texas at Austin

★ WORKSHOP 2: ENUMERATIVE GEOMETRY AND CALABI–YAU VARIETIES, October 15–19, 2013

The total number of registered participants was **56**.

- **Abouzaid, Mohammed**, Columbia University
- **Abramovich, Daniel**, Brown University
- **Amir-Khosravi, Zavosh**, University of Toronto
- **Bertolini, Marco**, Duke University
- **Brav, Christopher**, Institute for Advanced Study
- **Bryan, Jim**, University of British Columbia
- **Ceballos, Cesar**, York University
- **Chan, Kwokwai**, The Chinese University of Hong Kong
- **Chen, Qile**, Columbia University
- **Cheung, Man-Wai**, University of California San Diego
- **Cooper, Yiam**, Harvard University
- **Costello, Kevin**, Northwestern University
- **Delieu, Thomas**, Université Paul Sabatier
- **Diaconescu, Duiliu-Emanuel**, University of Alberta
- **Fang, Bohan**, Columbia University
- **Filippini, Sara**, Fields Institute
- **Fukaya, Kenji**, Simons Center, Stony Brook University
- **Garcia-Robaso, Alberto**, University of Toronto
- **Gonzalez-Dorrego, Maria R**, University of Toronto

- **Gross, Mark**, University of California San Diego
- **Gualtieri, Marco**, University of Toronto
- **Jinzenji, Masao**, Hokkaido University
- **Karigiannis, Spiro**, University of Waterloo
- **Kasa, Michael**, University of California San Diego
- **Kelly, Tyler**, University of Pennsylvania
- **Kontsevich, Maxim**, Institute des Hautes Études Scientifiques (IHES)
- **Lau, Siu-Cheong**, Harvard University
- **Laza, Radu**, Stony Brook University
- **Li-Bland, David**, Berkeley
- **Marcus, Steffen**, University of Utah
- **Molnar, Alexander**, Queen's University
- **Moraru, Ruxandra**, University of Waterloo
- **Movasati, Hossein**, Instituto Nacional de Matemática Pure e Aplicada (IMPA)
- **Odaka, Yuji**, Imperial College/Kyoto University
- **Overholser, Douglas (Peter)**, Fields Institute
- **Perunicic, Andrija**, Fields Institute
- **Quigley, Callum**, University of Alberta
- **Rayan, Steve**, University of Toronto
- **Rose, Simon**, Fields Institute
- **Ross, Dustin**, University of Michigan
- **Ruan, Yongbin**, University of Michigan
- **Ruddat, Helge**, Fields Institute
- **Schaug, Andrew**, University of Michigan
- **Selmani, Sam**, McGill University
- **Silversmith, Robert**, University of Michigan
- **Soibelman, Yan**, Kansas State University
- **Soloviev, Fedor**, University of Toronto

- **Thompson, Alan**, Fields Institute
- **Tseng, Hsian-Hua**, Ohio State University
- **van Garrel, Michel**, Fields Institute
- **Yui, Noriko**, Queen's University/Fields Institute
- **Zaslow, Eric**, Northwestern University
- **Zhang, Zheng**, Stony Brook University
- **Zhu, Yuecheng**, University of Texas at Austin
- **Zinger, Aleksey**, Stony Brook University

★ WORKSHOP 3: PHYSICS AROUND MIRROR SYMMETRY, October 21–25, 2013 at Perimeter Institute

The total number of registered participants was **36**.

- **Bobev, Nikolay**, Perimeter Institute for Theoretial Physics
- **Borot, Gaeten**, Max-Planck Institute Bonn and MIT
- **Bouchard, Vincent**, University of Alberta
- **Couso, Ricardo**, University of Santiago Compostela
- **Diaconescu, Emanuel**, University of Alberta
- **Doroud, Nima**, Perimeter Institute for Theoretical Physics
- **Favero, David**, University of Alberta
- **Filippini, Sara**, Fields Institute
- **Gahramanov, Ilmar**, Humboldt University
- **Gaiotto, Davide**, Perimeter Institute for Theoretical Physics
- **Gomis, Jaume**, Perimeter Institute for Theoretical Physics
- **Gualtieri, Marco**, University of Toronto
- **Hori, Kentaro**, Kavli IPMU, Tokyo
- **Kachru, Shamit**, Stanford University

- **Karigiannis, Spiro**, University of Waterloo
- **Klemm, Albrecht**, University of Bonn
- **Koroteev, Peter**, Perimeter Institute for Theoretical Physics
- **Meinikov, IIarion**, Albert Einstein Institute
- **Molnar, Alex**, Queen's University
- **Moraru, Ruxandra**, University of Waterloo
- **Okuda, Takuya**, University of Tokyo
- **Overholser, Peter**, Fields Institute
- **Perunicic, Andrija**, Fields Institute
- **Quigley, Callum**, University of Alberta
- **Rose, Simon**, Fields Institute
- **Ruddat, Helge**, Fields Institute
- **Schaposnick, Laura**, University of Illinois
- **Salmani, Sam**, McGill University
- **Soibelman, Yan**, Kansas State University
- **Thompson, Alan**, Fields Institute
- **van Garrel, Michel**, Fields Institute
- **Walcher, Johannes**, McGill University
- **Yui, Noriko**, Queen's University
- **Zhu, Yuecheng**, University of Texas at Austin

★ The Concentrated Graduate Courses for Workshop 4, November 11–15, 2013

The total number of registered participants was **31**.

- **Amir-Khosravi, Zavosh**, University of Toronto
- **Ceballos, Cesar**, York University

- **De Silva, Genival**, Washington University in St Louis
- **Filippini, Sara**, Fields Institute
- **Garcia-Raboso, Alberto**, University of Toronto
- **Gonzalez-Dorrego, Maria R**, University of Toronto
- **Gualtieri, Marco**, University of Toronto
- **Hayama, Tatski**, Tsinghua University
- **Keast, Ryan**, Washington University in St Louis
- **Kelly, Tyler**, University of Pennsylvania
- **Kerr, Matt**, Washington University in St Louis
- **Laza, Radu**, Stony Brook University
- **Luk, Kevin**, University of Toronto
- **Molnar, Alexander**, Queen's University
- **Odaka, Yuji**, Imperial College London
- **Overholser, Douglas (Peter)**, Fields Institute
- **Perunicic, Andrija**, Fields Institute
- **Peters, Chris**, Université Grenoble I
- **Rahmati, Mohammad Reza**, CIMAT
- **Rayan, Steve**, University of Toronto
- **Rose, Simon**, Fields Institute
- **Ruddat, Helge**, Fields Institute
- **Schütt, Matthias**, University of Hannover
- **Selmani, Sam**, McGill University
- **Soloviev, Fedor**, University of Toronto
- **Thompson, Alan**, Fields Institute
- **van Garrel, Michel**, Fields Institute
- **Voisin, Claire**, CNRS
- **Wang, Yicao**, University of Toronto
- **Yui, Noriko**, Queen's University/Fields Intitute

- **Zhang, Zheng**, Stony Brook University
- **Zhu, Yuecheng**, University of Texas at Austin

★ WORKSHOP 4: HODGE THEORY IN STRING THEORY, November 18–22, 2013

The total number of registered participants was **54**.

- **Abramovic, Robert**, Stony Brook University
- **Amir-Khosravi, Zavosh**, University of Toronto
- **Ballard, Matthew**, University of South Carolina
- **Ceballos, Cesar**, York University
- **Charles, Francois**, Massachusetts Institute of Technology (MIT)/Orsay
- **Da Silva, Genival**, Washington University in St Louis
- **Dettweiller, Michael**, University of Bayreuth
- **Doran, Charles**, University of Alberta
- **Faber, Eleonore**, University of Toronto
- **Filippini, Sara**, Fields Institute
- **Findelton, Suzanne**, Queen's University
- **Garbagnati, Alic**, Universita degil Studi di Milano
- **Garcia-Raboso, Alberto**, University of Toronto
- **Gualtieri, Marco**, University of Toronto
- **Halic, Mihai**, no affiliation
- **Harder, Andrew**, University of Alberta
- **Hayama, Tatsuki**, Tsinghua University
- **Karakoc, Selcuk**, Tulane University
- **Karigiannis, Spiro**, University of Waterloo
- **Katzarkov, Ludmil**, Univerity of Vienna/University of Miami

- **Keast, Ryan**, Washington University of St Louis
- **Kelly, Tyler**, University of Pennsylvania
- **Kerr, Matt**, Washington University of St Louis
- **Laza, Radu**, Stony Brook University
- **Luk, Kevin**, University of Toronto
- **Malmendier, Andreas**, Colby College
- **Molnar, Alexander**, Queen's University
- **Moraru, Ruxandra**, University of Waterloo
- **Morrison, David**, University of California Santa Barbara
- **Movasati, Hossein**, Instituto Nacional de Matemática Pure e Aplicada (IMPA)
- **Mustata, Anca**, University College Cork
- **Odaka, Yuji**, Imperial College London
- **Overholser, Douglas (Peter)**, Fields Institute
- **Pearlstein, Gregory**, Texas A& M University
- **Perunicic, Andrija**, Fields Institute
- **Peters, Chris**, Universite Grenoble I
- **Rahmati, Mohammad Reza**, CIMAT
- **Rayan, Steve**, University of Toronto
- **Rose, Simon**, Fields Institute
- **Ruddat, Helge**, Fields Institute
- **Sacca, Guilia**, Stony Brook University
- **Selmani, Sam**, McGill University
- **Soloviev, Fedor**, University of Toronto
- **Thompson, Alan**, Fields Institute
- **Usui, Sampei**, Osaka University
- **van Gareel, Michel**, Fields Institute
- **Viosin, Claire**, Institute de Mathématiques de Jussieu
- **Walcher, Johannes**, McGill University

- **Wang, Yicao**, University of Toronto
- **Xu, Jinxing**, University of Science and Technology of China
- **Yui, Noriko**, Queen's University/Fields Institute
- **Zhang, MIngwei**, University of Science and Technology of China
- **Zhang, Zheng**, Stony Brook University
- **Zhu, Yuecheng**, University of Texas at Austin
- **Zuo, Kang**, University of Mainz