**Banff International Research Sta**
for Mathematical Innovation and Discover

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# Modular Forms in String Theory (16w5009)

Arriving in Banff, Alberta Sunday, September 25 and departing Friday September 30, 2016

## Organizers

Charles Doran (University of Alberta, Canada)

Ling Long (Louisiana State University)

Yasuhiro Goto (Hokkaido University of Education at Hakodate, Japan)

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## Objectives

One of the principal goals of this workshop is to compare new developments since the last one, and give directions to future researches in the interface of number theory and string theory. We continue to look at various modular forms, zeta-functions, $L$-series, Galois representations, arising from Calabi--Yau manifolds, conformal field theory, quantum field theory, $4D$ gauge theory, and Feynman diagrams and integrals. The subject area of interest might be classified into not clearly disjoint sets which include:

(a) Modularity of Galois representations, and arithmetic questions. Recent powerful modularity lifting theorems, originated in the Shimura--Taniyama conjecture, have resulted in new modularity results for new classes of Calabi--Yau varieties over number

fields. During the workshop, we will discuss generalizations of these modularity results in the spirit of the Langlands Programme and investigate potential applications such as finding physical meanings of the special values of $L$L-functions for Calabi--Yau varieties.

(b) From Monstrous moonshine, to Mathieu moonshine and beyond. The moonshine phenomena relate the geometry of K3 surfaces to the representation theory of sporadic groups like the Monster group and the Mathieu group $M_{24}$M24 as well as modular forms. Very recently, physicist Hartmut Monien and his research group computed the Belyi map which realizes $M_{24}$M24 as the Galois group of a 3-point ramified covering of $CP^1$CP1. Further theoretical developments as well as their impacts on computations of modular forms, the conformal field theory, modular tensor categories and quantum groups are highly desirable.

(c) Mirror symmetry. There are various versions of ``mathematical mirror symmetry'' (e.g., Kontsevich's Homological Mirror Symmetry Conjecture, and the proposal of Strominger--Yau--Zaslow). Of particular interest for this workshop are the arithmetic aspects of each of these. An approach is through Picard--Fuchs (PF) differential equations associated to Calabi--Yau families, and periods of differential forms of Calabi--Yau manifolds. The PF equations are classically related to various modular and automorphic forms: quasimodular, harmonic, Siegel, Jacobi, and quantum modular forms. These modular forms have begun to play an important role in the Type II/Heterotic string duality. We will discuss recent developments of modular forms, their applications to physics and investigate further directions.

(d) Conformal field theory, and modular forms. Relationship with monstrous moonshine, modular tensor categories and quantum groups.

(e) Automorphic black hole entropy. This is the latest development in string theory to explain the entropy of black holes, which is described by certain automorphic forms, e.g., Siegel modular forms.

(f) Topological string theory (Gromov-Witten theory and its generalizations), and modular and generalized modular forms; Gromov-Witten invariants, Wall-crossing formula, Donaldson--Thomas invariants, and their generalizations, etc, and their possible relations to various modular forms.

(g) Other topics such as Feymnan diagrams and integrals, and their relationship to multiple zeta-values, and motives; Toric and combinatorial methods for Calabi--Yau manifolds.

Besides highlighting significant scientific progress in the topic areas and cultivating new directions and innovative methods, we also aim at mentoring the career developments of junior researchers by providing career advice and collaboration opportunities.