# Vertex Algebras, Factorization Algebras, and Applications

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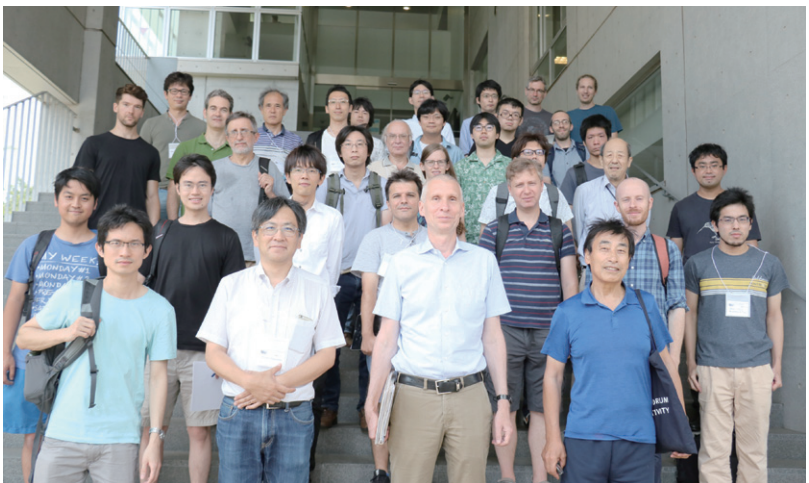
From July 17 to July 21, 2018, Kavli IPMU hosted a workshop on "Vertex algebras, factorization algebras, and applications," organized by B. Feigin (HSE Moscow and Kyoto University), M. Kapranov (Kavli IPMU), and H. Nakajima (Kavli IPMU).

Vertex algebras are fundamental algebraic structures underlying conformal field theories in two dimensions. With the impetus given by the AGT conjecture, the recent couple of years have seen intense activity relating field theories in 2 and 4 dimensions. In particular, there emerged deep relations between vertex algebras and the geometry of smooth 4-dimensional manifolds.

At the same time, vertex algebras are particular cases of factorization algebras, a concept that makes sense in any number of dimensions and provides a mathematical descriptions of quantum field theories. Factorization structures and factorization homology also serve as a mathematical language for a local-to-global "integration" formalism in pure mathematics. They have also served as crucial tools in representation theory of affine Lie algebras and quantum groups. The emerging relation of factorization structures in 2 and 4 dimensions is an extremely promising area of development, of importance both in mathematics and physics. The conference brought together experts in these related areas as well as younger researchers from Japan and overseas. The talks of S. Gukov and B. Feigin were devoted to the exciting connections between vertex algebra and smooth 4-manifolds. In particular, classical constructions related to vertex algebras (such as coset models) obtained a new meaning from the 4-dimensional topology point of view (plumbing, Kirby moves, etc.).

The talk of T. Arakawa was devoted to a new "geometrization" approach to vertex algebras based on the concept of associated varieties, which provide natural vertex Poisson algebras and ordinary Poisson manifolds. This approach also establishes a connection to the mathematical analysis of Coulomb branches of 4-dimensional field theories. A. Braverman, in his talk, explained a wider and more conceptual categorical framework for some of these questions. The talk of T. Kuwabara, devoted to "chiralization" of hypertoric manifolds, made several steps in the opposite direction, going from certain Poisson manifolds to vertex algebras.



D. Gaitsgory presented a vertex algebra approach to the quantum Langlands correspondence, understood as equivalence of categories of twisted D-modules. In the talks of S. Raskin, L. Chen, and D. Yang, several aspects of the connection between vertex algebras, affine Lie algebras, and quantum groups were investigated, with applications to the Langlands correspondence playing an important role.

The talks of T. Creutzig, K. Kawasetsu and T. Nishinaka were devoted to various aspects of vertex algebras coming from affine Lie algebras at admissible level. A. Linshaw talked about realizing W-algebras as specializations of vertex algebras depending on parameters.

Various applications of factorization structures (including those in higher dimensions) were given in the talks of E. Cliff, J. Francis, B. Hennion, Q. Ho, Y. Kremnitzer, and V. Schechtman. Relations with Hall algebras (which play a role in some mathematical aspects of the AGT conjectures) were discussed by E. Vasserot.

# IGM2018: Revealing Cosmology and Reionization History with the Intergalactic Medium

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On September 18–21, 2018, the 4-day workshop titled "IGM2018: Revealing Cosmology and Reionization History with the Intergalactic Medium" was held at the Kavli IPMU. The goal of this workshop was to bring theorists and observers working on the intergalactic medium (IGM) across a range of cosmic history and observational methods to discuss the interplay between cosmology and reionization history. Our invited speakers ranged from experts on the cosmic microwave background, high-redshift galaxy observations, quasar observations, Lyman-alpha forest cosmology, and 21cm studies. Over 100 participants showed up from both within Japan and also all over the world including Asia, Europe and North America.

An intriguing development in recent years is that the optical depth to electron scattering as measured through the cosmic microwave background has been creeping lower, implying that hydrogen reionization occurred later than previously assumed, with a midpoint around $z = 7.7$. This means that the most distant quasars, and the foreground IGM absorption seen in their spectra, are now directly probing the epoch of reionization! Indeed, Fred Davies (UCSB) demonstrated direct neutral fraction constraints from the hydrogen damping wing in the most distant ($z = 7.5$) quasar spectrum, which bodes well for the exciting possibility of directly measuring the evolution of the neutral fraction across the epoch of reionization with future samples of high-redshift quasars. Xiaohui Fan (Arizona), in particular described ambitious efforts to find more high-redshift quasars at $z > 7$.

At slightly lower redshift, we heard about efforts to understand the nature of optically-thick Gunn-Peterson troughs at $z \sim 5.5$, when hydrogen reionization should have been completed. George Becker (UC Riverside) showed narrow-band imaging results from Subaru Hyper Suprime-Cam indicating a deficit of Lyman-alpha emitters near these dark troughs, which could be interpreted as being due to UV background fluctuations or even pockets of late reionization as advocated by Laura Keating (CITA).

The effects of reionization persist to lower redshifts especially in the temperature and pressure evolution of the IGM. Elisa Boera (UC Riverside) discussed constraints on the thermal properties of the IGM using the Lyman-alpha forest power spectrum at $z \sim 4-5$, while Michael Walther (UCSB) showed impressive forest power spectrum constraints over 12 Gigayears of cosmic time from $z \sim 0-5$. We also had presentations on cosmological constraints using the IGM, first via a comprehensive review by Andreu Font-Ribera (UCL) on the use of Lyman-alpha forest baryon oscillation signal to early expansion history of the universe. Nathalie Palanque-Delabrouille (CEA Saclay) then presented 1D power-spectrum constraints on neutrino masses (from $z \sim 2-3$ data) as well as warm dark matter and sterile neutrino masses from $z \sim 4–5$ data. During the discussions it was clear that the understanding of reionization and thermal history of the IGM is becoming a high priority for mitigating this systematic in Lyman-alpha forest cosmology.

Overall it was a successful workshop, and the participants remarked on the multi-disciplinary nature which allowed for discussions between scientists who would not usually encounter each other at meetings.