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## Integral Representations of Quantum Invariants of Three-Manifolds

In this talk we focus on finite dimensional integral representations of topological invariants of three-manifolds which are motivated by resurgence.

Our first example will be the Witten-Reshetikhin-Turaev (WRT) quantum invariant of a three-manifold with a colored link. Our corresponding integral representation, which is joint with Andersen and Hindson, is motivated by Witten's works on analytic continuation of quantum Chern-Simons field theory. Our integral representation leads to a formal semi-classical expansion in terms of Chern-Simons invariants of flat connections in accordance with Witten's asymptotic expansion conjecture.

Additionally, I will present a new result, a proof of Witten's asymptotic expansion conjecture for the WRT invariants of a Seifert fibered integral homology three-sphere  $M$ , which is joint with Andersen, Han, Li, Sauzin and Sun. This proof is based on resurgence, quantum modularity and a previous result, which is joint with Andersen and inspired by work of Gukov, Marino and Putrov, namely the so-called radial limit theorem for  $M$ . This theorem concerns the BPS  $q$ -series invariant of  $M$  defined by Gukov, Pei, Putrov and Vafa, and the theorem asserts that as  $q$  tends to a root of unity, this series limits the WRT invariant of  $M$  at that root of unity.

Finally, based on joint work with Murakami, I will present a new integral formula for a certain average of the BPS  $q$ -series invariants of pairs  $(Y, b)$ , where  $Y$  is a general negative definite plumbed homology three-sphere  $Y$  and  $b$  is a spin- $c$  structure. This integral formula is used to establish, for this class of three-manifolds, the radial limit conjecture for non-semisimple quantum invariants due to Costantino, Gukov and Putrov. This asserts that the limit of this average of BPS  $q$ -series invariants is equal to the non-semisimple quantum invariant of  $Y$  defined by Costantino, Geer, Patureau and Mirand.

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