

Research description of Harshit Yadav

I use tensor categories to study algebraic structures arising from conformal field theory. My main objects of study are modular tensor categories (MTCs) and vertex operator algebras (VOAs); I use “modular tensor category” to mean a ribbon tensor category with trivial Müger center, not necessarily finite or semisimple. A central theme is understanding when VOA representation categories admit rigidity, ribbon structure, and nondegeneracy. In the semisimple case these properties underlie quantum invariants of knots and 3-manifolds, and they remain fundamental in nonsemisimple and logarithmic settings.

In two-dimensional conformal field theory, several key constructions relating VOAs have categorical counterparts. Extensions correspond to categories of local modules, orbifolds to G -extensions and equivariantization, cosets to categorical correspondences via algebras in Deligne products, and kernels of screening operators are conjecturally described by Yetter-Drinfeld categories. Several of these correspondences are well understood in the semisimple setting; my research develops them in nonsemisimple and infinite settings, where representation categories of logarithmic VOAs, quantum groups at roots of unity, and quantum supergroups naturally arise. Alongside this program, I develop algebraic tools including Frobenius algebras, Frobenius monoidal functors, and module categories, and use characteristic p methods to construct exotic fusion categories.

Local modules and VOA extensions. VOAs provide algebraic models for chiral two-dimensional conformal field theory [Bor86; FLM89], and under suitable finiteness and tensor-categorical hypotheses their representation categories are modular tensor categories [Hua05]. Given a VOA extension $V \subset W$, the extension defines a commutative algebra object A in $\mathcal{C} = \text{Rep}(V)$, and under suitable tensor-categorical hypotheses one recovers $\text{Rep}(W)$ as the category of local A -modules $\mathcal{C}_A^{\text{loc}}$ [KO02; CKM17]. The main difficulty is rigidity: proving that duals, ribbon structure, and nondegeneracy transfer through this construction is subtle. My work addresses this in three papers, extending the theory from finite to infinite settings.

In joint work with K. Shimizu [1], we gave general criteria for $\mathcal{C}_A^{\text{loc}}$ to be rigid and ribbon. For finite tensor categories, these criteria reduce to A being *exact* [EO04], a concrete categorical condition. This yields a nonsemisimple analogue of [KO02]: if \mathcal{C} is a finite MTC and A is a commutative indecomposable exact symmetric Frobenius algebra, then $\mathcal{C}_A^{\text{loc}}$ is again a finite MTC.

In joint work with T. Creutzig, R. McRae, and K. Shimizu [2], we applied these categorical results to VOAs, proving that if V is a strongly finite VOA with rigid representation category and $V \subset W$ is a simple extension with W strongly finite, then $\text{Rep}(W)$ is again rigid; and that rationality of V implies rationality of any simple VOA extension that is $\mathbb{Z}_{\geq 0}$ -graded. This removes a technical hypothesis on conformal dimensions that was previously needed, yielding short uniform proofs of rationality for families such as hook-type W -algebras. We also treated the weaker Grothendieck-Verdier setting [BD13], which appears frequently in logarithmic representation theory, providing criteria for rigidity of $\text{Rep}(V)$ from that of $\text{Rep}(W)$; these criteria were subsequently used to prove rigidity for the weight module category of affine \mathfrak{sl}_2 at admissible levels [CMY24].

In recent work [3], we extended the local modules construction to ind-completions of braided finite tensor categories, where the algebra object may lie in the ind-completion of $\text{Rep}(V)$ rather than in $\text{Rep}(V)$ itself. We proved that finitely generated local modules inherit rigidity and ribbon structure under explicit conditions, verified these for simple current algebras, and constructed ribbon tensor categories from unrolled quantum groups of $\mathfrak{gl}(1|1)$.

Orbifolds, cosets, and screening operators. For the orbifold construction, given a finite group G acting on a VOA V , the representation categories of V and V^G are related through G -extensions and equivariantization. The classification of G -extensions [ENO10] was previously carried out for tensor categories; in [4], we extended it to pivotal and spherical finite tensor categories, classifying pivotal graded extensions via pivotal analogues of the Brauer-Picard groups.

For the coset construction, a conformal extension $V \otimes V' \subset W$ produces a commutative algebra in $\text{Rep}(V) \boxtimes \text{Rep}(V')$, and one seeks to reconstruct $\text{Rep}(V)$ from $\text{Rep}(V')$ and this algebra. Previous categorical frameworks for this problem [Frö+06] required semisimplicity; in ongoing work [5], we extend them to the finite nonsemisimple setting, requiring only exactness of the algebra.

In free-field realizations of VOAs, screening operators on a lattice VOA V can, under suitable hypotheses, give rise to a Nichols algebra B inside $\text{Rep}(V)$ [Len21]. The logarithmic Kazhdan-Lusztig conjecture [Len25] predicts that the kernel sub-VOA has representation category equivalent to the Yetter-Drinfeld category ${}^B_B\mathcal{YD}(\mathcal{C})$. In ongoing work [6], we develop the structural theory of this category: we classify its ribbon structures, describe its Müger center and invertible objects, and for B a Nichols algebra of diagonal type establish an abelian equivalence $\text{Rep}^{\text{wt}}(\overline{U}_q^H(\mathfrak{g})) \cong {}^B_B\mathcal{YD}(\mathcal{C})$ with the weight module category of the restricted unrolled quantum group. Combining with [3], we use simple current algebras in the Yetter-Drinfeld category to construct ribbon tensor categories from unrolled quantum $\mathfrak{sl}(m|n)$ and $\mathfrak{osp}(1|2)$. In related ongoing work [7], we study tensor categories from affine Lie superalgebras using these techniques.

Algebras and module categories. A separate thread of my work develops algebraic and module-theoretic tools used in the constructions above. In [8], we proved that the Frobenius property lifts through filtered deformations, and showed that every exact module category over a symmetric finite tensor category has the form \mathcal{C}_A for a Frobenius algebra A . We also showed in [9] that two classes of quasi-Frobenius algebras admit non-counital Frobenius structures. In my solo paper [10], I proved that under suitable conditions on a monoidal adjunction $L \dashv R$, the right adjoint R is Frobenius monoidal if and only if $R(\mathbb{1}_{\mathcal{D}})$ is a Frobenius algebra.

On the module-category side, in my solo paper [11] I introduced *unimodular module categories* and proved that unimodularity is equivalent to a natural tensor functor $\Psi: \mathcal{Z}(\mathcal{C}) \rightarrow \mathcal{C}_{\mathcal{M}}^*$ having Frobenius monoidal right adjoint, enabling the transfer of Frobenius algebras from $\mathcal{C}_{\mathcal{M}}^*$ to the Drinfeld center $\mathcal{Z}(\mathcal{C})$. In [12], we extended nondegeneracy and factorizability to braided module categories, generalizing Shimizu's theorem [Shi19]. In [13], we proved that \otimes -Frobenius functors preserve unimodularity and pivotality.

Exotic fusion categories in characteristic p . A major challenge is to construct exotic fusion categories, those that lie outside the known sources of finite groups and quantum groups. In joint work with T. Gannon and A. Schopieray [14], we use characteristic p techniques together with the lifting theorem of [ENO05] to construct Haagerup-Izumi fusion categories, which are exotic. Instead of solving the relevant systems of equations over \mathbb{C} , we find solutions over fields of characteristic p , establish existence over finite fields \mathbb{F}_{p^r} , and lift to characteristic zero. For Haagerup-Izumi categories parametrized by $G = \mathbb{Z}/n$ with odd $n \leq 19$, we have shown that there exists a positive density of primes p for which these categories admit a model over \mathbb{F}_p .

Together, these results develop tensor-categorical methods for extensions, orbifolds, cosets, and screening operators for VOAs, alongside new constructions using characteristic p techniques and the structural theory of module categories.

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