Category \mathcal{O} for quantum groups

(joint work with Henning Haahr Andersen)

Volodymyr Mazorchuk (Uppsala University)

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Various quantum groups

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 U_A — the $A = \mathbb{Z}[v, v^{-1}]$ -form of U_v (generators $E_i^{(r)}$, $F_i^{(r)}$, $K_i^{\pm 1}$)

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Quantum Frobenius: $Fr_q: U_q \rightarrow U$ (roughly $E_i^{(mk)} \mapsto e_i^{(m)}$)

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(Integral) weight modules: $M \in U_q$ -mod such that $M = \bigoplus_{\lambda \in \mathbb{Z}^n} M_\lambda$,

$$M_{\lambda} = \{ v \in M : K_i^{\pm 1} v = q^{\pm d_i \lambda_i} v \}$$

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Category \mathcal{O}_q :

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Main question: What about \mathcal{O}_q ?

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Comparing \mathcal{O}_{int} and $\overline{\mathcal{O}_q}$

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The special block of \mathcal{O}_q

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Define the **special block** \mathcal{O}_q^{spec} as the Serre subcategory of \mathcal{O}_q generated by $L_q(\lambda)$, $\lambda \in k\mathbb{Z}^n + (k-1)\rho$.

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Theorem. The categories \mathcal{O}_{int} and \mathcal{O}_{a}^{spec} are equivalent.

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The equivalence is given by first applying $_^{[k]}$ and then tensoring with the Steinberg module (simple h. w. module with h. w. $(k-1)\rho$)

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First consequences

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 U_q is a Hopf algebra

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 \mathcal{O}_q has "projective endofunctors" given by tensoring with fin. dim. modules

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- ▶ O_q has the double centralizer property with respect to projective injective modules, i.e.

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- *O_q* has enough projectives;
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- Every object in \mathcal{O}_q has finite length;
- ▶ O_q has the double centralizer property with respect to projective injective modules, i.e. for any projective P there is an exact sequence

$$0 \rightarrow P \rightarrow X \rightarrow Y$$

with both X and Y projective injective.

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Corollary: There is a bijection between indecomposable tilting modules and simple modules in \mathcal{O}_q .

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Recall: Blocks of \mathcal{O}_q might have infinitely many simples.

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Decomposition theorem for structural modules

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Decomposition theorem for structural modules

write
$$\lambda = \lambda^0 + k\lambda^1$$
, $0 \le \lambda_i^0 < k$.

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Proposition (Lusztig). $L_q(\lambda) \cong L(\lambda^1)^{[k]} \otimes L_q(\lambda^0)$.

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if $L(\lambda)$ is finite dimensional, denote by $Q_q(\lambda)$ the projective cover of $L(\lambda)$ in the category of finite dimensional U_q -modules.

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Theorem. $T_q(\lambda) \cong T(\lambda^1 - \rho)^{[k]} \otimes Q_q(k\rho + w_o \cdot \lambda^0).$

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Proposition (BGG-reciprocity). $(P_q(\lambda) : \Delta_q(\mu)) = [\Delta_q(\mu) : L_q(\lambda)]$

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Theorem. The formal character of $L_q(\lambda)$ equals

$$\sum_{y \in W, \ z \in W_{l}} (-1)^{l(yw) + l(zx)} P_{y,w}(1) P_{z,x}(1) \mathrm{ch} \Delta_{q} (l(yw^{-1} \cdot \lambda^{1}) + zx^{-1} \cdot \lambda^{0}))$$

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Theorem. For regular λ the multiplicity $(T_q(\lambda) : \Delta_q(\mu))$ equals

$$\sum_{y,z} P_{y,w}(1) Q_{z,x}(1)$$

where the sum runs over those $y \in W$, $z \in W_l$ for which $\mu = lyw^{-1} \cdot (\lambda^1 - \rho) + zx^{-1} \cdot \lambda^0$.

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 $P_{x,y}$ — Kazhdan-Lusztig polynomials; $Q_{x,y}$ — their "inverses"

Theorem. The formal character of $L_q(\lambda)$ equals

$$\sum_{y \in W, \ z \in W_{l}} (-1)^{l(yw) + l(zx)} P_{y,w}(1) P_{z,x}(1) \mathrm{ch} \Delta_{q} (l(yw^{-1} \cdot \lambda^{1}) + zx^{-1} \cdot \lambda^{0}))$$

Theorem. For regular λ the multiplicity $(T_q(\lambda) : \Delta_q(\mu))$ equals

$$\sum_{y,z} P_{y,w}(1) Q_{z,x}(1)$$

where the sum runs over those $y \in W$, $z \in W_l$ for which $\mu = lyw^{-1} \cdot (\lambda^1 - \rho) + zx^{-1} \cdot \lambda^0$.

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