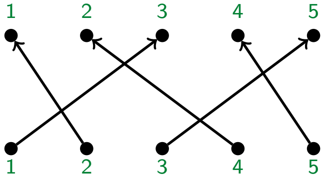
Tensor spaces, braid groups, and some remarkable quotients.

Zajj Daugherty

September 26, 2014

Motivating example: Schur-Weyl Duality

The **symmetric group** S_k (permutations) as diagrams:



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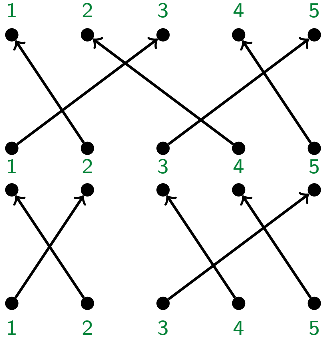

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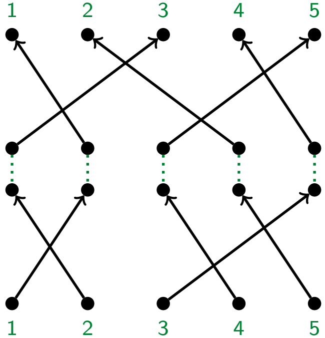

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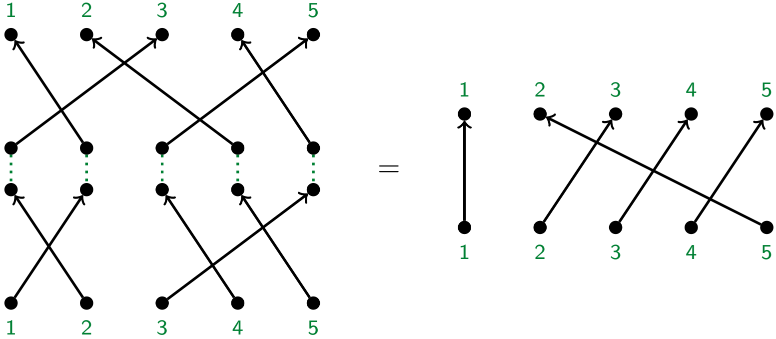

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$\mathrm{GL}_n(\mathbb{C})$ acts on $\mathbb{C}^n \otimes \mathbb{C}^n \otimes \cdots \otimes \mathbb{C}^n = (\mathbb{C}^n)^{\otimes k}$ diagonally.

$$g \cdot (v_1 \otimes v_2 \otimes \cdots \otimes v_k) = gv_1 \otimes gv_2 \otimes \cdots \otimes gv_k.$$

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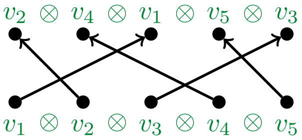

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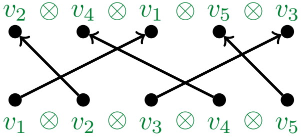
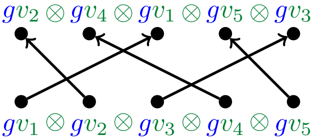


These actions commute!



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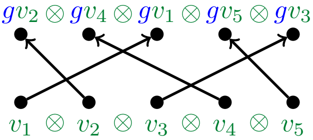

Motivating example: Schur-Weyl Duality

Schur (1901): S_k and GL_n have commuting actions on $(\mathbb{C}^n)^{\otimes k}$.

Even better,

$$\underbrace{\mathrm{End}_{\mathrm{GL}_n}\left((\mathbb{C}^n)^{\otimes k}\right)}_{\substack{\text{(all linear maps that}\\ \text{commute with } \mathrm{GL}_n)}} = \underbrace{\pi(\mathbb{C}S_k)}_{\substack{\text{(img of } S_k\\ \text{action)}}} \quad \text{and} \quad \mathrm{End}_{S_k}\left((\mathbb{C}^n)^{\otimes k}\right) = \underbrace{\rho(\mathbb{C}\mathrm{GL}_n)}_{\substack{\text{(img of } \mathrm{GL}_n\\ \text{action)}}}.$$

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Why this is exciting:

The double-centralizer relationship produces

$$(\mathbb{C}^n)^{\otimes k} \cong \bigoplus_{\lambda \vdash k} G^\lambda \otimes S^\lambda \quad \text{as a } \mathrm{GL}_n\text{-}S_k \text{ bimodule,}$$

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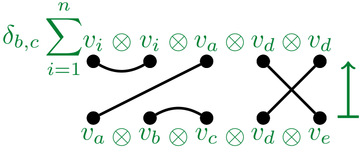
For example,

$$\mathbb{C}^n \otimes \mathbb{C}^n \otimes \mathbb{C}^n = \left(G^{\square\square\square} \otimes S^{\square\square\square}\right) \oplus \left(G^{\begin{smallmatrix}\square&\square\\ \square\end{smallmatrix}} \otimes S^{\begin{smallmatrix}\square&\square\\ \square\end{smallmatrix}}\right) \oplus \left(G^{\begin{smallmatrix}\square\\ \square\\ \square\end{smallmatrix}} \otimes S^{\begin{smallmatrix}\square\\ \square\\ \square\end{smallmatrix}}\right)$$

More centralizer algebras

Brauer (1937)
Orthogonal and symplectic groups (and Lie algebras) acting on $(\mathbb{C}^n)^{\otimes k}$ diagonally centralize the **Brauer algebra**:



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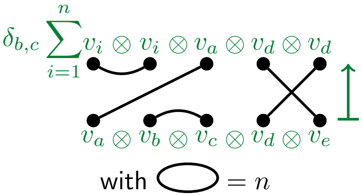

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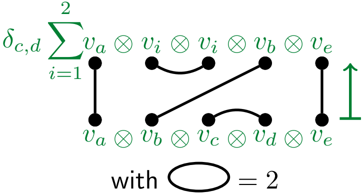

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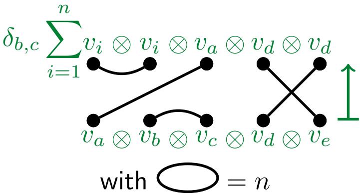

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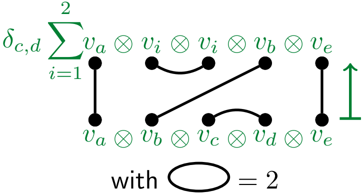

Either way:
Diagrams encoding maps $V^{\otimes k} \to V^{\otimes k}$ that commute with the action of some classical algebra.

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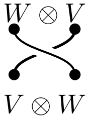
$\mathcal{U} \otimes \mathcal{U}$ has an invertible element $\mathcal{R} = \sum_{\mathcal{R}} R_1 \otimes R_2$ that yields a map

$$\check{\mathcal{R}}_{VW} : V \otimes W \longrightarrow W \otimes V$$



that (1) satisfies braid relations, and

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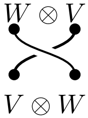

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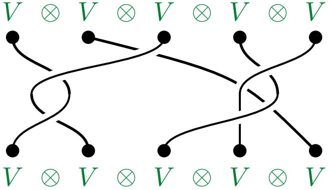

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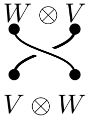

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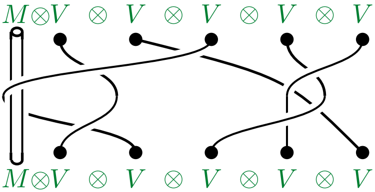
The one-pole/affine braid group shares a commuting action with $\mathcal{U}$ on $M \otimes V^{\otimes k}$:



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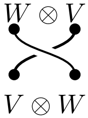

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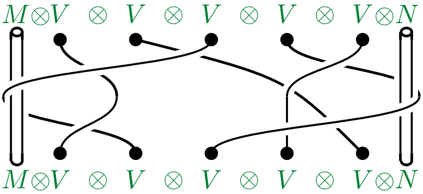
The two-pole braid group shares a commuting action with $\mathcal{U}$ on $M \otimes V^{\otimes k} \otimes N$:



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Lie grp/alg

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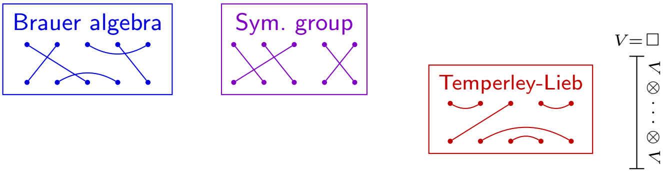
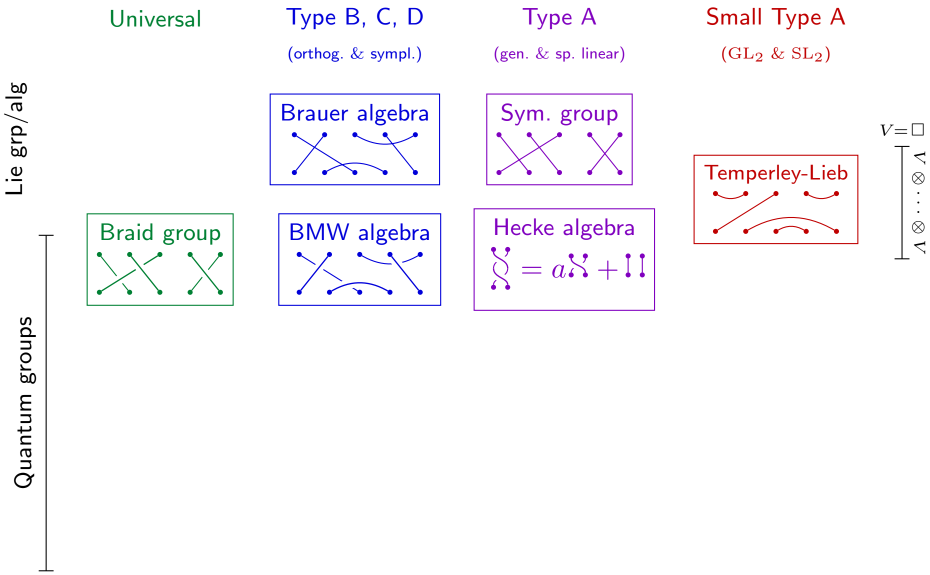
Type A
(gen. & sp. linear)

Small Type A
(GL_2 & SL_2)

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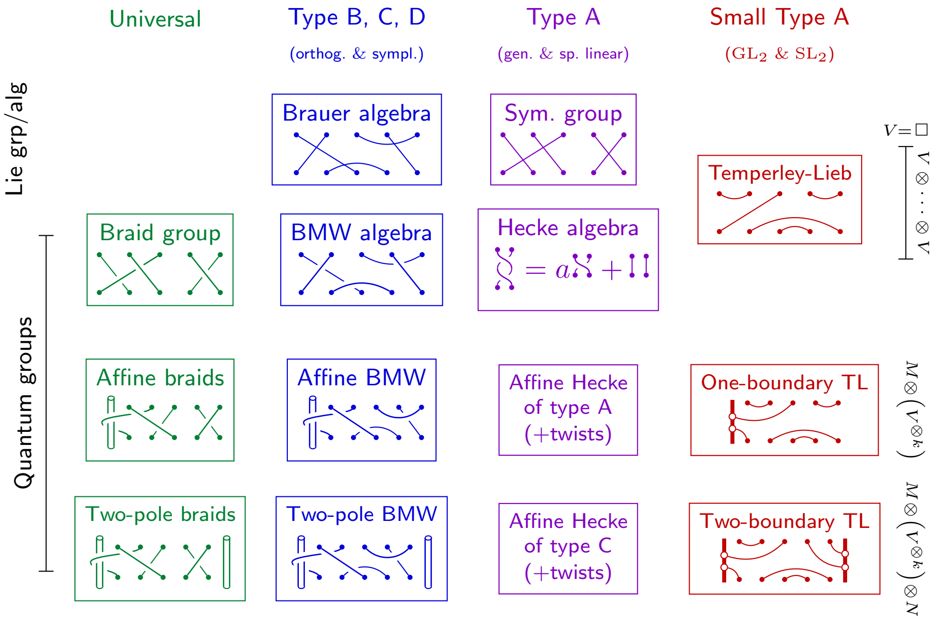

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$= a \quad + $
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Affine BMW
Affine Hecke of type A (+twists)
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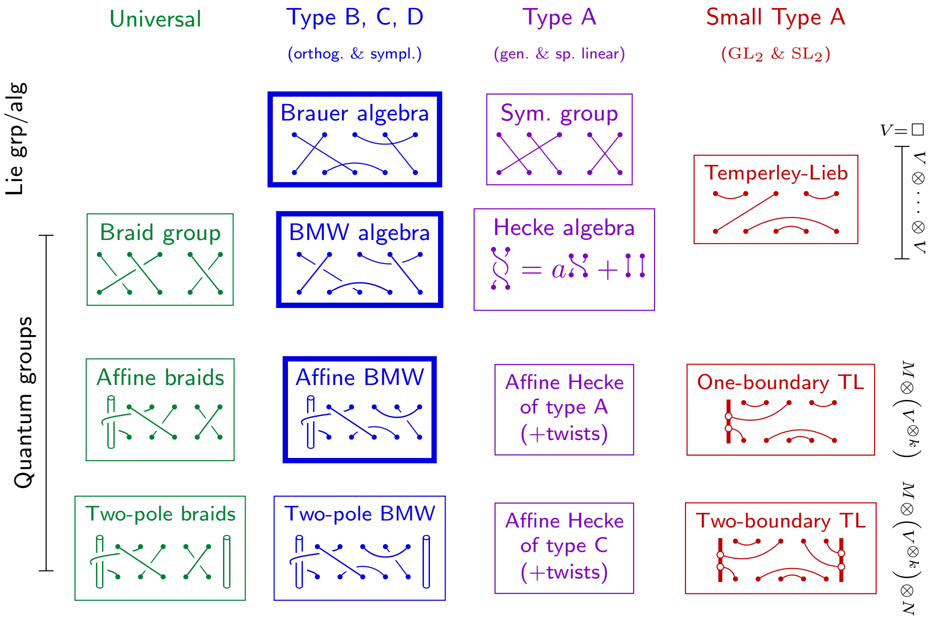
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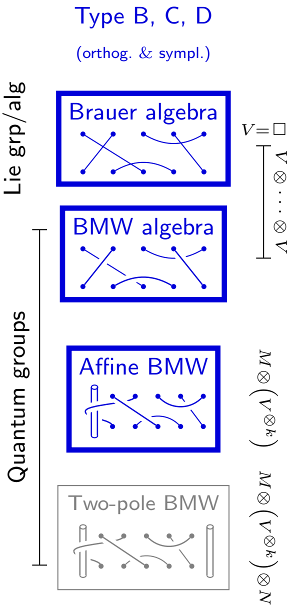

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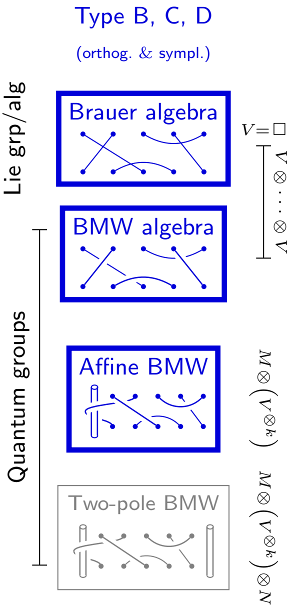

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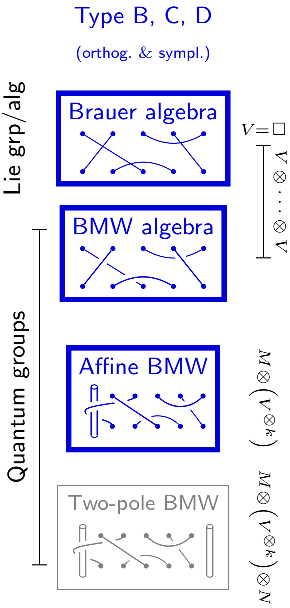
Implicitly showed an action on $M \otimes V^{\otimes k}$ commuting with the action of the Lie algebras of types B, C, D.



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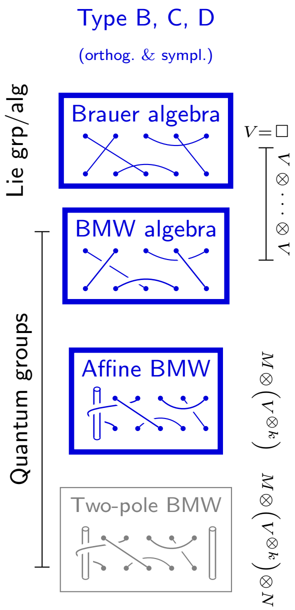

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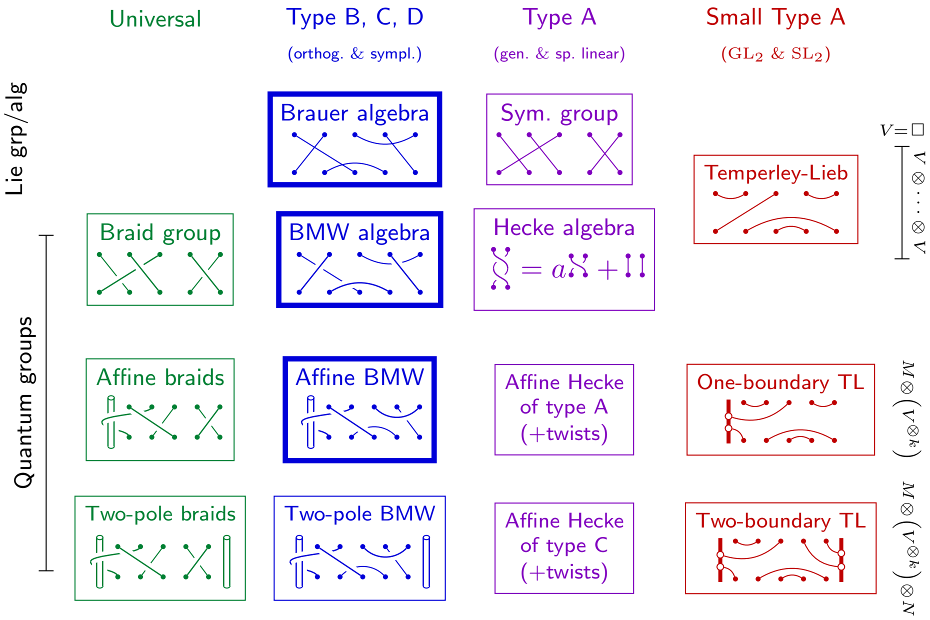
D.-Ram-Virk: Used these centralizer relationships to study these two algebras simultaneously. Some results:

(a) The center of each algebra.
(b) Difficult "admissibility conditions" handled.
(c) Powerful "intertwiner" operators.
(More to come)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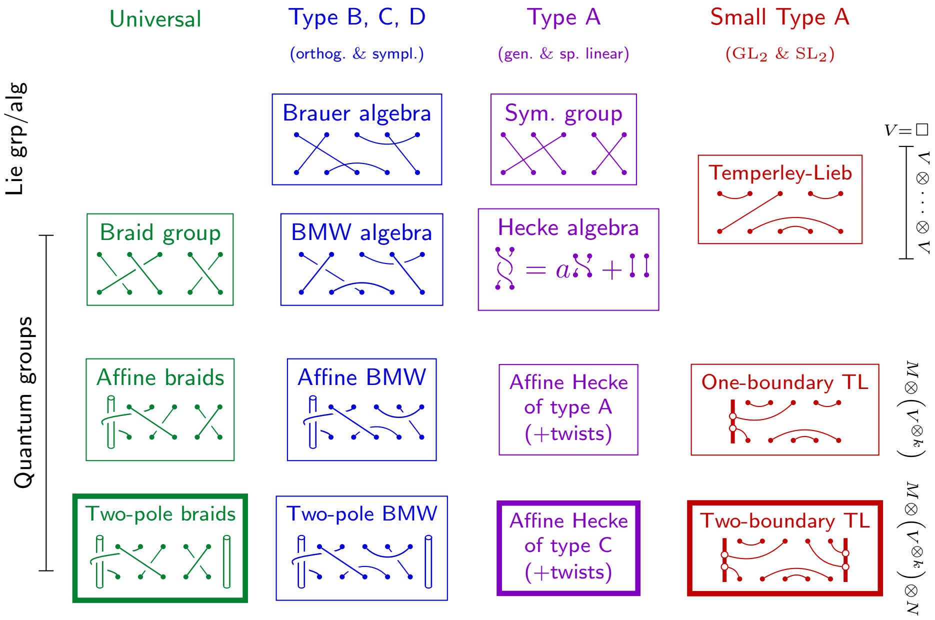
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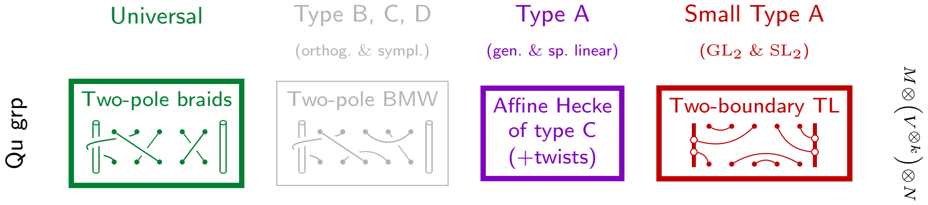

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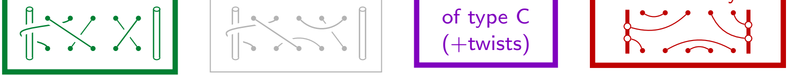

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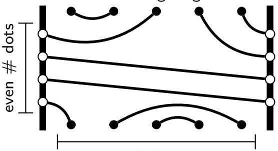

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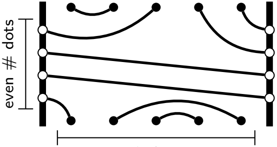


De Gier, Nichols (2008): Explored representation theory of TL_k using diagrams and established a connection to the affine Hecke algebras of type A and C.

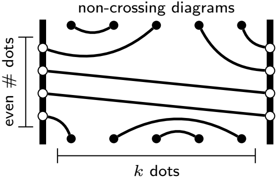
	Universal	Type B, C, D	Type A	Small Type A
		(orthog. & sympl.)	(gen. & sp. linear)	(GL_2 & SL_2)

Qu grp

$M \otimes \left(V^{\otimes k}\right) \otimes N$

Two boundary algebras:

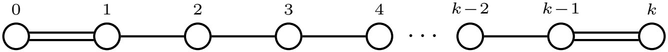
Mitra, Nienhuis, De Gier, Batchelor (2004): Studying the six-vertex model with additional integrable boundary terms, introduced the two-boundary Temperley-Lieb algebra TL_k:



De Gier, Nichols (2008): Explored representation theory of TL_k using diagrams and established a connection to the affine Hecke algebras of type A and C.

D. (2010): The centralizer of $\mathfrak{gl}_n$ acting on tensor space $M \otimes V^{\otimes k} \otimes N$ displays type C combinatorics for good choices of M, N, and V.

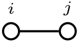
Affine type C Hecke algebra and two-boundary braids

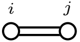


Fix constants t_0, t_k, and $t = t_1 = \cdots = t_{k-1}$. The affine Hecke algebra of type C, $\mathcal{H}_k$, is generated by $T_0, T_1, \ldots, T_k$ with relations

$$\underbrace{T_iT_j\ldots}_{m_{i,j}\text{ factors}} = \underbrace{T_jT_i\ldots}_{m_{i,j}\text{ factors}} \qquad \text{where} \qquad m_{i,j} =$$

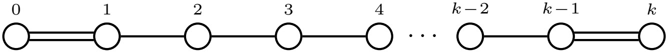
2 if 

3 if 

4 if 

and $T_i^2 = (t_i^{1/2} - t_i^{-1/2})T_i + 1$.

Affine type C Hecke algebra and two-boundary braids



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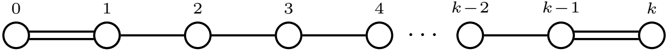

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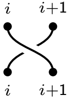
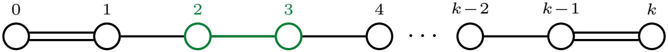
The two-boundary (two-pole) braid group B_k is generated by

$T_k =$  $T_0 =$  and $T_i =$ 

for $1 \leq i \leq k-1$.

Affine type C Hecke algebra and two-boundary braids



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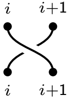
$T_k =$  $T_0 =$  and $T_i =$ 

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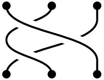
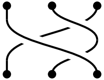
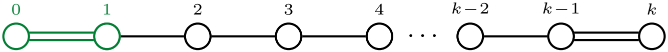
Relations:

$T_iT_{i+1}T_i =$  $=$  $= T_{i+1}T_iT_{i+1}$

Affine type C Hecke algebra and two-boundary braids



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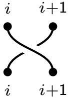
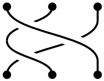
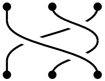
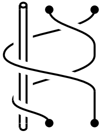
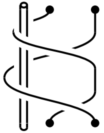
$T_k =$  $T_0 =$  and $T_i =$  for $1 \le i \le k-1$.

Relations:

$T_iT_{i+1}T_i =$  $=$  $= T_{i+1}T_iT_{i+1}$

$T_1T_0T_1T_0 =$  $=$  $= T_0T_1T_0T_1$

Theorem (D.-Ram, degenerate version in [Da10])

1. *Let* $U = U_q\mathfrak{g}$ *for any complex reductive Lie algebras* $\mathfrak{g}$.
   Let M, N, *and* V *be finite-dimensional modules.*

   The two-boundary braid group B_k *acts on* $M \otimes (V)^{\otimes k} \otimes N$ *and this action commutes with the action of* U.

2. *If* $\mathfrak{g} = \mathfrak{gl}_n$, *then (for appropriate choices of* M, N, *and* V*),*
   the affine Hecke algebra of type C, H_k, *acts on* $M \otimes (V)^{\otimes k} \otimes N$ *and this action commutes with the action of* U.

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Some results:

(a) A combinatorial classification and construction of irreducible representations of H_k (type C with distinct parameters).

(b) A diagrammatic intuition behind otherwise unwieldy calculations in TL_k and H_k.

(c) (Working towards) a classification of the representations of TL_k in [dGN08] via central characters.

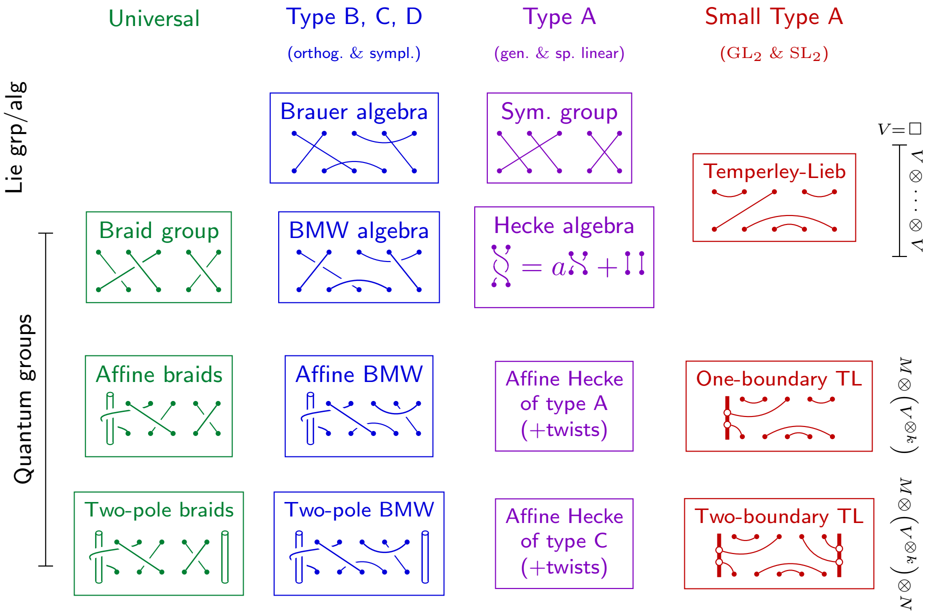
Thanks!

[Da10] *Degenerate two-boundary centralizer algebras*, Pacific J. Math., 258-1 (2012) 91–142.

[DRV14] *Affine and degenerate affine BMW algebras: the center*, with Arun Ram and Rahbar Virk, to appear in to appear in Osaka J. Math., 51-1 (2014).

[DRV13] *Affine and degenerate affine BMW algebras: actions on tensor space*, with Arun Ram and Rahbar Virk, Selecta Math., 19-2 (2013) 611–653.

[DR] *Two boundary Hecke Algebras and the combinatorics of type* $(C_n^\vee, C)$ *Hecke algebras*, with Arun Ram (in progress).



Universal
Type B, C, D
(orthog. & sympl.)
Type A
(gen. & sp. linear)
Small Type A
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Lie grp/alg
Quantum groups
Brauer algebra
Sym. group
Temperley-Lieb
Braid group
BMW algebra
Hecke algebra
$= a$ $+$
Affine braids
Affine BMW
Affine Hecke of type A (+twists)
One-boundary TL
Two-pole braids
Two-pole BMW
Affine Hecke of type C (+twists)
Two-boundary TL
$V = \square$
$V \otimes \cdots \otimes V$
$M \otimes (V^{\otimes k})$
$N \otimes (V^{\otimes k}) \otimes M$