

Cat of reps sl_2

$$\text{f-d} \quad (U_q(sl_2)) \longleftrightarrow$$

V_i -fund rep

on

$$E\left(\begin{smallmatrix} \cdot & F \\ 0 & v_b \end{smallmatrix}\right)$$

$$V_i^{\otimes n} = \bigoplus_{\alpha=0}^n V_i^{\otimes n}(\alpha)$$

\uparrow
weight sp

$$\underline{2k-n}$$

$$V_i^{\otimes n}(\alpha) \longleftrightarrow K_0(D_{k,n-\alpha})$$

$$v_\mu \longleftrightarrow [M_\mu]$$

$$V_i^{\otimes n} \rightarrow V_n$$

End(P_n)

?!

$$V_n \cong \bigoplus_{\alpha=0}^n V_i^{\otimes n} \quad H_{k,n} = H^*(Gr(k, n))$$

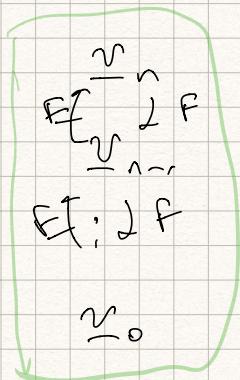
irr $n \geq 0$

$sl(2)$.

$$v_{\mu} \Rightarrow \sum_{\alpha} v_{\mu}$$

$k\alpha$'s
 $n-\alpha$'s

$$|\mu| = n - \alpha$$



basis of V_n

$$V_n \subset V_i^{\otimes n} \text{ on cat. level.}$$

$$v_{\mu} \quad P_{\mu} \in D_{k,n-\alpha}$$

build a set of V_n

via $H_{k,n}$

$$\dim H_{k,n} = \binom{n}{\alpha}$$

Cat \mathcal{D} for sl_n

$$\simeq K_0 \left(\bigoplus_{\alpha=0}^n D_{k,n-\alpha} \right)$$

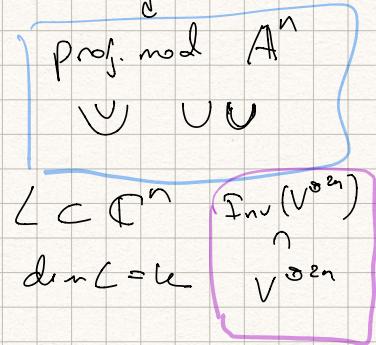
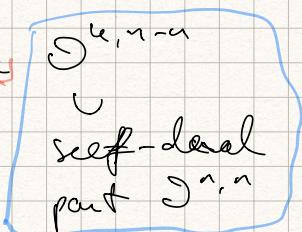
? quadratic dual

$$K_0 \left(\bigoplus_{\alpha=0}^n D_{k,n-\alpha} \right)$$

\uparrow

max. paral. blocks.

big proj module P_k



$$\begin{array}{ccc} \underline{\mathcal{H}_{k,n}\text{-mod}} & \hookrightarrow & \mathcal{H}_{k,n}\text{-pmod} \\ \mathcal{G}_0(\mathcal{H}_{k,n}) & \xleftarrow{\quad \cong \quad} & \mathcal{K}_0(\mathcal{H}_{k,n}) \\ & \xleftarrow{\text{distr}_{k,n}} & \xleftarrow{\cong} \end{array}$$

$\underline{[\mathcal{H}_{k,n}]} = (\underline{k}) \underline{[\mathcal{L}_k]}$

built from unique simple fd module $\mathcal{L}_k \subset \underline{\mathbb{C}}$

V_n 2 integral lattices

$$\begin{array}{c} \underline{V_n} \\ \downarrow \\ \text{inf.} \quad \underline{V_{n-1}} \quad \text{integral} \\ \text{lattice} \quad , \quad \text{lattice} \\ \downarrow \quad \downarrow \\ V_{n-k} \quad \underline{V_0} \end{array}$$

$$\begin{array}{c} \underline{V} \\ \downarrow \\ \underline{V'_k} \end{array}$$

$$\underline{V'_k} = \binom{n}{k}^{-1} \underline{V_k}$$

Category V_n

$$C_n = \bigoplus_{k=0}^n \underline{\mathcal{H}_{k,n}\text{-mod}}$$

iff E, F to numbers

$$\begin{array}{ccc} A & & \text{isom if } A \text{ has fin. hom} \\ \mathcal{K}_0(A) & \xrightarrow{\varphi} & \mathcal{G}_0(A) \\ \overbrace{[P]} & \longleftrightarrow & \overbrace{[P]} \\ \mathcal{L} & \xrightarrow{\text{dim}} & \mathcal{L} \quad \text{if } A \text{ locally} \\ & \cong & \text{lk.} \\ & & \text{End}(A) = k \end{array}$$

$$\mathcal{G}_r(k, n) \quad \mathcal{L}'/k$$

$$\mathcal{F}\ell(k, r+k, n) = \left\{ 0 \subset \underline{L} \subset \underline{L'} \subset \underline{\mathbb{C}^n} \right. \\ \left. \begin{array}{l} \dim \underline{L} = k \\ \dim \underline{L'} = r+k \end{array} \right.$$

$$\begin{array}{ccc} \mathcal{F}\ell(k, r+k, n) & & \\ \downarrow & \downarrow & \\ \mathcal{G}_r(k, n) & \mathcal{G}_r(r+k, n) & \end{array}$$

view as
ring, bimodule only

$$\mathcal{H}_{k,r+k,n} - \text{bimodule over } (\mathcal{H}_{k,n}, \mathcal{H}_{r+k,n})$$

free $\mathcal{H}_{k,n}\text{-mod}$, $\mathcal{H}_{r+k,n}\text{-mod}$.

$$\begin{array}{ccc} & \mathcal{H}^*(\mathcal{F}\ell^{||}(k, r+k, n)) & \\ & \uparrow & \downarrow \\ \mathcal{H}^*(\mathcal{G}_r(k, n)) & & \mathcal{H}^*(\mathcal{G}_r(r+k, n)) \end{array}$$

$$m \quad \epsilon \quad \epsilon(m)$$

$$\mathcal{F} \colon \text{H}_{u,n}\text{-mod} \xrightarrow{\cong} \text{H}_{u+1,n}\text{-mod}$$

$$E(M) = \underbrace{H_{u, v, t, n}}_{H_{\alpha, n}} \otimes M$$

$$F(M) = \mu_{v, v+1, v} \otimes N$$

Prop \mathcal{E}, \mathcal{F} left E, F in $sl(2)$. They are $U_f(sl_2)$

biadjoint, rich alg. of mod-funs. between arb.

products of \mathcal{E}, \mathcal{F} .

$$\mathcal{E}^m \rightarrow \mathcal{E}^m$$

mult. by 1st Chern class
of can. line bundle $\mathcal{E} \rightarrow E$

$$\mathcal{E}^2 \rightarrow \mathcal{E}^2$$

Push-pull systems

$$\begin{array}{ccc}
 & H^*(Z) & \\
 \nearrow & \downarrow & \searrow \text{to Cohomology} \\
 H^*(X) & \xrightarrow{\quad P^* \quad} & H^*(Y)
 \end{array}$$

$$\frac{K[x_1 \dots x_n]}{J}$$

$\text{Sym}_{n,n-k} \hookrightarrow \text{Sym}_n \text{ under } \underline{\text{S}}_n \otimes \underline{\text{S}}_{n-k}$

$$\text{Sym}_n \otimes \text{Sym}_{n-m} \quad \text{Sym}_n = \langle [x_1 \dots x_n] \rangle^{\text{Sym}_n}$$

\cup free Sym_n -mod rank $\binom{n}{k}$.

$$R_{u,n-a} = \text{Sym}_n \otimes \text{Sym}_{m-a}$$

$$R_n = \frac{\text{Sym}_n}{\cup}$$

$$\begin{array}{c} H^k(GL(n)) \leftarrow (Gr(k,n)) \\ H^0(GL(n)) \rightarrow (-) \end{array}$$

$$= H^b(\cdot)$$

mod out by assignment ideal in Sym_n) I_n - pos. deg.

$$\text{cl}^{\text{reg}} \underset{\text{Symm, p. degn}}{\longrightarrow} e_1 \dots e_n = 0$$

$$R_n / I_n \cong H^*(\bullet)$$

$$R_{n,m}/R_{n-m} \cong H^*(Gr(n,m)) \quad] \text{ f.d.}$$

\mathcal{E}, \mathcal{F} forms heeden bimodules of their \mathcal{A} .
to look for gen, rels $\frac{\text{rel}}{\text{gen}}$ exist
hold parallel

Aaron cat of q.s.l(e)

$$\begin{array}{c} \mathcal{U} \quad \mathcal{E}, \mathcal{F} \\ \cong \\ \left(\begin{array}{c} \mathcal{U}^+ (\mathcal{U}_2) \quad \mathcal{E}^n \\ \mathcal{U}^+ (\mathcal{O}) \end{array} \right) \end{array} \quad \text{simplex-level calc.}$$

CR, Rouquier
Chuang-Rouquier

monoidal cat via gen & relations.

$$sl(2) \quad \mathcal{E}^n$$

$$\begin{array}{c} ||| | \\ 1 \quad 2 \quad n \end{array} \quad id: \mathcal{E}^n \xrightarrow{id} \mathcal{E}^n$$

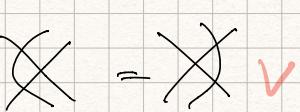
$$\begin{array}{c} x \\ \downarrow \\ \mathcal{E} \xrightarrow{\downarrow} \mathcal{E} \end{array}$$

generators \rightarrow

relations

i) everything far away computes

$$\boxed{f \mid f = f \mid \boxed{f} \quad X \mid \boxed{f} = X \mid \boxed{f}}$$

2) $X = 0$ 

3) $X - X = 1$ 

$$\begin{array}{c} \mathcal{E}^n \\ \text{---} \\ \text{---} \\ \mathcal{E}^n \end{array}$$

$$\begin{array}{c} \mathcal{E}^m \\ \cancel{\text{---}} \\ \cancel{\text{---}} \\ \mathcal{E}^n \end{array}$$

$\cancel{\text{---}}$ $n \neq m$

$$\begin{array}{c} x_i \\ \mid \quad \mid \\ 1 \quad 2 \quad i \quad i+1 \\ \downarrow \quad \downarrow \\ \mathcal{E}^n \end{array}$$

$$\cancel{\times} - \times = 11$$

multiplied by x_i endomorphism of Pol_n

$f \mapsto x_i f$

$\sum_i x_i \partial_i$ Demazure - BGG divided diff operator

$$\partial_i f(x_1, x_2) = \frac{f(x_1, x_2) - f(x_2, x_1)}{x_1 - x_2} \in \text{Sym}_2$$

$$\partial_i f = \frac{f - f^{\leftrightarrow}}{x_i - x_{i+1}}$$

← transport x_i, x_{i+1} in f .

$$\partial_i^2 = 0 \quad \boxed{\partial_i^2 = 0} \quad \checkmark$$

$$\partial_i \partial_{i+1} \partial_i = \partial_{i+1} \partial_i \partial_{i+1} \quad \checkmark$$

$$x_1 \partial_1 - \partial_1 x_2 = 1 \quad \partial_1 x_1 - x_2 \partial_1 = 1$$

$$\cancel{\times} - \times = 11$$

$$x_i \partial_i - \partial_i x_{i+1} = 1$$

pictorial

$$f \times$$

algebraic

$$x_i, \partial_i$$

End of Pol_n

as module over
sym

$$\partial_i(gf) = g\partial_i(f)$$

symmetric in x_i, x_m

geometric

x_i - multiply by 1st Chern class of line bundle

$$\text{Pol}_n = H^*_{GL_n}(F)$$

$$\text{Sym}_n = H^*_{GL_n}(\circ)$$

F

∂_i P^i \perp largest i -R subspace
 P^i

Def NH_n (nilpotent alg) alg gen by x_i, ∂_i acting on P_{oln} .

Prop 1) NH_n has above defining relations.

2) $NH_n \rightarrow \text{End}(P_{\text{oln}})$ is an Sym_n isom.

3) $\frac{NH_n}{P_{\text{oln}}} \cong \frac{\text{Mat}(n!, \text{Sym}_n)}{n!} \xrightarrow[n!]{\text{idemp}} \frac{\text{idemp}}{\text{Sym}_n}$

$\cong \text{Sym}_n$ " $\frac{n!}{n!}$ of 1 " " $\frac{n!}{n!}$ of 1 "

works in gradable case $n! \mid n!$

Can think of $\bigcup_{n \geq 0} NH_n$ as describing a monoidal cat

with a generating object E . E^n

$$\text{Hom}(E^n, E^m) = \begin{cases} NH_n & n=m \\ 0 & \text{otherwise.} \end{cases}$$

$$n=0 \quad NH_0 = \mathbb{k}$$

$$n=1 \quad \vdots \quad NH_1 = \mathbb{k}[x_1]$$

$$n=2 \quad \begin{matrix} \text{ } & \text{ } & \text{ } \\ \text{ } & \text{ } & \text{ } \\ \text{ } & \text{ } & \text{ } \end{matrix} \quad \begin{matrix} \text{ } & \text{ } & \text{ } \\ \text{ } & \text{ } & \text{ } \\ \text{ } & \text{ } & \text{ } \end{matrix} \quad \begin{matrix} \text{ } & \text{ } & \text{ } \\ \text{ } & \text{ } & \text{ } \\ \text{ } & \text{ } & \text{ } \end{matrix} \quad \begin{matrix} \text{ } & \text{ } & \text{ } \\ \text{ } & \text{ } & \text{ } \\ \text{ } & \text{ } & \text{ } \end{matrix} \quad NH_2 \cong \text{Mat}(2, \text{Sym}_2)$$

$$\cancel{X} = \cancel{X} + \cancel{X} = X \quad \cancel{X} = X$$

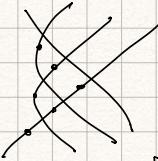
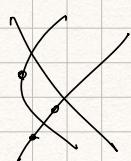
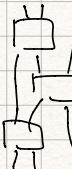
$$\cancel{X} = X \quad e_1 = X \quad e_1^2 = e_1$$

$$1 - e_1 = 1 - X = -X$$

$$\begin{pmatrix} \times & \times \\ \times & -\times \end{pmatrix} \xrightarrow{\text{check signs}} \begin{pmatrix} x & \cancel{x} \\ \cancel{x} & x \end{pmatrix} \quad \begin{pmatrix} e_{11} & e_{12} \\ e_{21} & e_{22} \end{pmatrix} \quad e_i; e_{ji} = e_{i\bar{j}}$$

$$\text{Sym}_2 \cong \langle x_1 \mp x_2, x_1 x_2 \rangle \quad \{ | \leftarrow | \{ , \} \}$$

$$e_i = \begin{cases} \square \\ \square \\ \times \end{cases}$$



min. idempotent

$$\deg x_i = 2, \deg \partial_i = -2$$

$$\frac{2}{\varepsilon^2} \quad \underline{q \approx q'}$$

$$\underline{\text{PGL}_2} \cong \text{Sym}_2 \cdot 1 \oplus \text{Sym}_2 \cdot 2,$$

diff in deg is 2

$$\begin{matrix} \varepsilon^2 \\ \text{End } (\varepsilon^n) \\ \varepsilon^2 \end{matrix} \quad \text{add idemp. to our category} \quad \text{(idempotent completion)} \quad \text{Karabé envelope}$$

$$C, \varepsilon, \varepsilon^2, \varepsilon^3, \dots$$

$$\rightarrow \text{Kar}(C)$$

$$\underline{\varepsilon^{(n)}} = (\varepsilon^n, e_{(n)})$$

$$\frac{1}{n!} \varepsilon^n \quad \varepsilon^{(n)}$$

$$\varepsilon^n = \bigoplus_{n!} \varepsilon^{(n)} \quad \overset{\text{min. idemp.}}{\uparrow}$$

$$\underline{\varepsilon^{(n)}} = \frac{1}{n!} \varepsilon^n$$

$$\underline{E^{(n)}} = \frac{1}{n!} E^n$$

$$\varepsilon^n = \bigoplus \underline{(\varepsilon^{(n)}) [n]!}$$

$$\varepsilon^2 = \varepsilon^{(2)} \{1\} \oplus \varepsilon^{(2)} \{-1\}$$

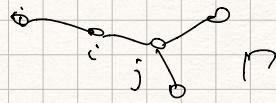
Categorifying divided powers of an operator.

$$E, X \rightarrow \varepsilon,$$

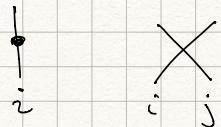
\mathcal{U}^+ (say) simply-laced

some relations of \mathcal{U}^+

Generalize NH_n



algebras strands colored by vertices (simple roots)



$R(v)$

$$v = \sum_i \frac{v_i \cdot i}{\#}$$

of i-strands.

Each i-rel's in NH_n

NH_n

$$\begin{array}{c} \times \\ \backslash \\ i \\ / \\ i \end{array} - \begin{array}{c} \times \\ \backslash \\ i \\ / \\ i \end{array} = \begin{array}{c} | \\ | \\ i \\ | \\ i \end{array}$$

$$\begin{array}{c} \times \\ \backslash \\ i \\ / \\ j \end{array} = \begin{array}{c} \times \\ \backslash \\ i \\ / \\ j \end{array}$$

$$\begin{array}{c} \bullet \\ \cap \\ \sqcap \end{array}$$

$$\begin{array}{c} \times \\ \backslash \\ i \\ / \\ i \end{array} - \begin{array}{c} \times \\ \backslash \\ i \\ / \\ i \end{array} = \begin{array}{c} | \\ | \\ i \\ | \\ i \end{array}$$

$$\begin{array}{c} \times \\ \backslash \\ i \\ / \\ j \end{array} = \begin{array}{c} \times \\ \backslash \\ i \\ / \\ j \end{array}$$

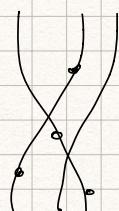
$$\begin{array}{c} \times \\ \backslash \\ i \\ / \\ j \end{array} = \left\{ \begin{array}{l} 0 \quad i=j \quad \leftarrow NH_2 \\ \begin{array}{c} | \\ | \\ i \\ | \\ j \end{array} \\ \text{---} \\ \begin{array}{c} | \\ | \\ i \\ | \\ j \end{array} + \begin{array}{c} | \\ | \\ i \\ | \\ j \end{array} \end{array} \right\}$$

$$\begin{array}{c} \times \\ \backslash \\ i \\ / \\ j \end{array} = \begin{array}{c} \times \\ \backslash \\ i \\ / \\ j \end{array}$$

except

$$\begin{array}{c} \times \\ \backslash \\ i \\ / \\ j \\ i \end{array} - \begin{array}{c} \times \\ \backslash \\ i \\ / \\ j \\ i \end{array} = \begin{array}{c} | \\ | \\ i \\ | \\ j \\ i \end{array}$$

$R(v)$



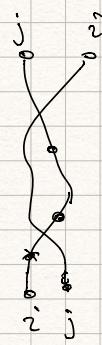
$$\mathcal{E}^n \rightarrow \mathcal{E}^n \quad NH_n = \text{End}(\mathcal{E}^n)$$

$\mathcal{E}_i \quad i \in \Gamma$

$b_{\text{on}}(\mathcal{E}_i, \mathcal{E}_{i_1}, \mathcal{E}_{j_1}, \mathcal{E}_{j_n})$

pictures / mod. rel's prescribed colors on boundary

$\text{Hom}(\varepsilon_i \varepsilon_j, \varepsilon_j \varepsilon_i)$

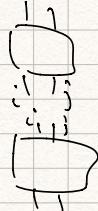


mod rel's.

get a basis of $R(v)$

$R(v)$ has idempotents

$$\underline{i} = i_1 i_2 \dots i_n$$



$\underline{i} \in \text{Seq}(v)$

i appears v_i times.

$$\text{Seq}(i \varepsilon_j) = \{\underline{i}, \underline{j}\}$$

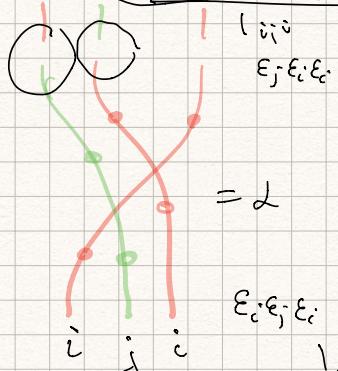
\underline{i} -idemp for $\text{Seq } \underline{i}$.

$$1 = \sum_{\underline{i} \in \text{Seq}(v)} 1_{\underline{i}}$$

$$1_{ij} + 1_{ji} \quad v = i \rightarrow j$$

$$\begin{matrix} | & | \\ i & j \end{matrix} + \begin{matrix} | & | \\ j & i \end{matrix} = \begin{matrix} | \\ | \end{matrix}$$

$\underline{R(v)}$ categorical space of v -weight space of $\mathcal{U}^f(\mathfrak{g})$



$$E_{i_1} E_{i_2} \dots E_{i_n}$$

\vee

$$E_i E_j, E_j E_i$$

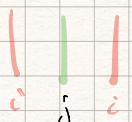
$$\mathcal{E}^2 \xrightarrow{\sim} \mathcal{E}^{(2)}$$

$$e_i \in \text{End}(\mathcal{E}^e)$$

$$2 1_{ijj} = 2$$

$$1_{iji} 2 = 0$$

$$1_{jii} 2 = 2$$



$$1_{iji}$$

$$\mathcal{E}_1, \mathcal{E}_2$$

$$\mathcal{E}_v = \bigoplus \mathcal{E}_{\underline{i}}$$

$$\mathcal{E}_{\underline{i}} = \mathcal{E}_{i_1} \mathcal{E}_{i_2} \dots \mathcal{E}_{i_n}$$

$$\mathcal{E}_{i_2 i \varepsilon_j} = \mathcal{E}_i \mathcal{E}_j \mathcal{E}_i \oplus \mathcal{E}_i \mathcal{E}_j \mathcal{E}_i \mathcal{E}_i \mathcal{E}_j \mathcal{E}_i$$

$$R(v) = \text{End}(\mathcal{E}_{i_2 i \varepsilon_j})$$

$$1_{\underline{i}}$$

$$R(v) = \bigoplus_{i,j \in \text{Sq}(v)} 1_{\underline{i}} R(v) 1_{\underline{j}}$$

$$\bigcup_b 1_b$$

$$, E_i f_j = f_j E_i$$

$$1 = \sum_{a \in \mathbb{B}^n} 1_a$$

$$R(v)$$

$$1_{\underline{i}}$$

$$R(v) 1_{\underline{i}} = P_{\underline{i}}$$

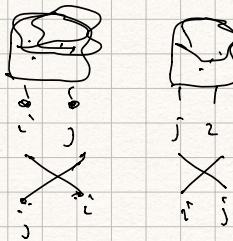
$\bigoplus_{i \in \text{Sq}(v)}$

$$R(v) 1_{\underline{i}} = P_{\underline{i}} \quad \text{- left proj } R(v) \text{- mod } \mathbb{B}$$

X_1 add by $R(v)$

$$E_i E_j \simeq E_j E_i$$

$$P_{ij} \simeq P_{ji}$$



$$P_{ij} \xleftrightarrow{\quad} P_{ji}$$

$$\begin{matrix} E_i & E_j \\ \cancel{s} & \cancel{s} \\ E_j & E_i \\ \cancel{i} & \cancel{i} \\ E_i & E_j \end{matrix}$$

$$\bigcup_{i,j} \begin{matrix} X \\ i \\ j \end{matrix} = \bigcup_{i,j} \begin{matrix} | \\ i \\ j \end{matrix} = 1_{ij}$$

$$XY = YX$$

$$X, Y$$

$$\begin{matrix} X \\ X \\ X \end{matrix} \quad \begin{matrix} Y \\ Y \\ Y \end{matrix} = \bigcup_{X,Y} \begin{matrix} | \\ | \end{matrix}$$

$$\begin{matrix} X \\ i \\ j \\ i \\ j \end{matrix} = \bigcup_{i,j} \begin{matrix} | \\ | \end{matrix}$$

$$e' - e'' = \bigcup_{i,j} \begin{matrix} | \\ | \\ i \\ j \\ i \end{matrix}$$

$$\begin{matrix} X \\ i \\ j \\ i \end{matrix} - \begin{matrix} X \\ i \\ j \\ i \end{matrix} = \bigcup_{i,j} \begin{matrix} | \\ | \\ i \\ j \\ i \end{matrix}$$

$$e' = \begin{matrix} X \\ i \\ j \\ i \end{matrix} \quad (e')^2$$

$$(e')^c = \text{Diagram } i \text{ (green)} + \text{Diagram } j \text{ (blue)} = \text{Diagram } k \text{ (green)}$$

$$= e^1 \text{ independent} \quad e'' = -$$

$$e^l + e^{''} = \frac{e^l - e^{''}}{e^a}$$

The diagram illustrates the decomposition of a crossing in a knot or link diagram. On the left, a crossing is shown with a red X over a green curve. A brace above the crossing indicates it is being split. The middle part shows the crossing resolved: the red line is moved over the green line, and the green line is moved under the red line, both ending at the same points. The right part shows the result as two separate strands: a red strand and a green strand, each with its own local orientation.

$$P_{ij} \simeq R(2i+j) e' \oplus R(2i+j) e''$$

$$E_i \otimes E_i = I$$

F. E. F.

$$e^i = \begin{matrix} \diagup & \diagdown \\ \text{c} & \text{j} & \text{c} \end{matrix} =$$

$$\begin{matrix} \sum E_i F_j \\ \text{[2]} \end{matrix} = \left(q - q^{-1} \right)$$

$$E_i F_j E_i = E_i^{(2)} F_j + f_j E_i^{(2)}$$

$$t_{\text{osc}} = e^u + e^r$$

$$t_{\text{obs}} = e'' + e'$$

$$t_{\text{obs}} = e'' + e^r$$

$$t_{\text{obs}} = e'' + e'$$

$$\mathcal{E}_j \mathcal{E}_i^{(2)} \xrightarrow{\quad} \cancel{\text{---}} \cancel{\text{---}}$$

$$\epsilon_i, \epsilon_j, \epsilon_c$$

(2) ϵ

$$\sum_i \xi_i \xi_i^* = \xi_j \xi_j^{(2)} \oplus \xi_i^{(2)} \xi_j$$

$$\underset{v}{\text{Thm}} \oplus_{K_0} (R(v) - \text{pmod}) \simeq U_{\mathbb{Z}}^+ (g)$$

$$[P_i] \longrightarrow E_i = E_{i_1} \dots E_{i_n}$$

$$[P_{i^n, e}] \longleftrightarrow E_i^{(n)}$$

$$R(v) \otimes R(v) \hookrightarrow R(v+v')$$

Ind, Res. \longrightarrow Groth. group

give mult, combt on $\underline{U_{\mathbb{Z}}^+ (g)}$

invert powers of q into
need. rules for $U_{\mathbb{Z}}^+ (g)$

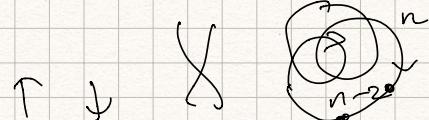
$$(x \otimes x') (y \otimes y') = q^{d(x', y)} E_i$$

$$xy \otimes x'y'$$

don't have center

weight spaces

E_i, F_i
 E_i, F_i - biadjoint



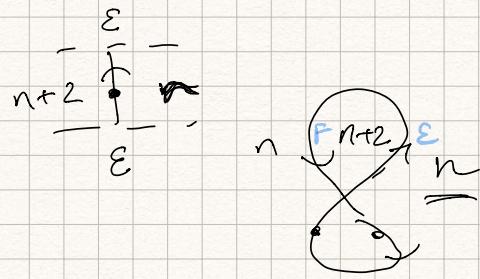
Brunandan-Kleshchev
Varagnolo-Vartoul.

Lands, Intro to Lie algs
& cat. quantum $sl(2)$

NH_n D_{eh}_n
 x_i, ∂_i

$\left(\bigoplus_{i \in \text{Seq}(n)} \text{pol}_i \right)$
 $R(v)$

K_i $q^{\cdot \cdot} \rightarrow$ grading shift



$$V(n) \xrightarrow{F} V(n+2)$$

$$\mathcal{N} = \{ -t \}$$

...

isofor
I
biogradeless
 ϵ_i, f_i

$$\binom{k_i}{n}$$

$$\frac{k_i(k_i-1)}{2}$$

$$\sim k_i \sim \underline{h_i}$$

Category

$$\frac{k(k-1)}{2}$$

$$\frac{k^2}{2}$$

$$\underline{\underline{NH_2}}$$