LQG Dynamics: Insights from PFT

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(work done in collaboration with Alok Laddha)

Papers:

- Talk is based on arXiv:1011.2463 (AL, MV). Formalism developed in CQG.27:175010,2010, PRD78:044008,2008 .
- Thiemann: arXiv:1010.2426

LQG Dynamics:Status

- Restrict attention to canonical theory.
- Construction of $\hat{C}_{ham}$ involves infinitely many ad- hoc choices so defn of quantum dynamics far from unique.
  - $C_{ham}(x)$ is local. Local field opertrs not defineable. Basic opertrs nonlocal.
  - Fix triangulation T. Construct $C_{ham,T}$ s.t. $\lim_{T\to\infty} C_{ham,T} = C_{ham}$. Replace $C_{ham,T}$ by $\hat{C}_{ham,T}$.
  - Problem: $\lim_{T\to\infty} \hat{C}_{ham,T}$ depends on finite T choices due to discont polymer repn.
- Consistency of theory reqires anomaly free repn of constraint algebra: $\{C_{ham}[N], C_{ham}[M]\} = C_{diff}[\vec{\beta}(N,M)]$
  Use this to fix ambiguities in defn of $\hat{C}_{ham}$?
- Problem: Constr algebra trivialises for all choices of $\lim_{T\to\infty} \hat{C}_{ham,T}$

Can PFT help?

- PFT does help:
  - Detailed structure uncannily similar to LQG
  - Know the right answers!

  More in Detail:

- Constraints H_+, H_- form Lie algebra. Can solve them in polymer repn unambiguously by Grp Averaging.
- $C_{ham} := \frac{H_+ - H_-}{\sqrt{q}}$, $C_{diff} = H_+ + H_-$ form Dirac algebra isomorphic to that of gravity.
- Do as in LQG: first diff avg then construct $\hat{C}_{ham}$.
- Analysis yields suggestions for LQG.
  - one should tailor repn of regulating holonomies to that of states being acted upon
  -look beyond "finite" smeared density weight one operators

Plan

- Review of Classical and Quantum (polymer) PFT
- Construction of $\hat{C}_{ham}$ following Thiemann in LQG
- Quantum Constraint Algebra
  - Trivialises as for LQG w.r.to Thiemann URS topology as well as on LM habitat
  - Trivialization suggests use of higher density Ham constr.
  - Nontrivial repn of higher density constraint algebra on new habitat (Time permitting!)
- Discussion

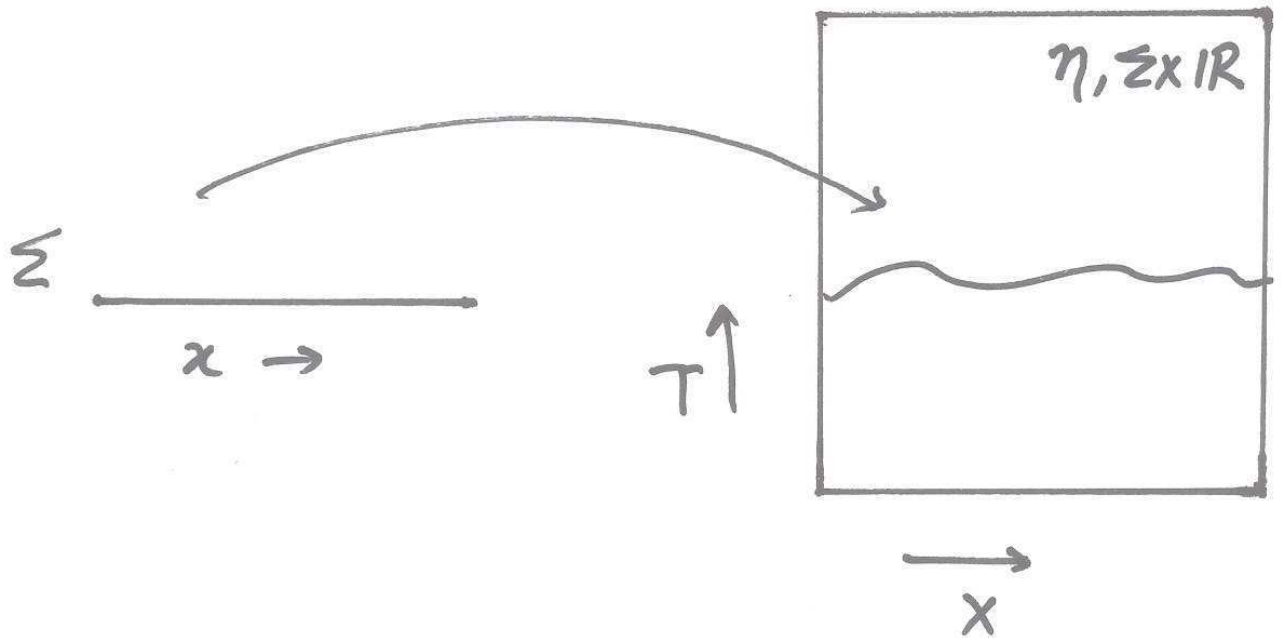
Classical PFT

- Free Scalar Field Action: $\mathbf{S}_0[f] = -\frac{1}{2}\int d^2X \eta^{AB}\partial_A f \partial_B f$
- Parametrize $X^A = (T, X) \to X^A(x^\alpha) = (T(x,t), X(x,t))$.
  $\Rightarrow \mathbf{S}_0[f] = -\frac{1}{2}\int d^2x \sqrt{\eta}\eta^{\alpha\beta}\partial_\alpha f \partial_\beta f$,
  $\eta_{\alpha\beta} = \eta_{AB}\partial_\alpha X^A \partial_\beta X^B$.
- Vary this action w.r.to f and 2 new scalar fields X^A:
  $S_{PFT}[f, X^A] = -\frac{1}{2}\int d^2x \sqrt{\eta(X)}\eta^{\alpha\beta}(X)\partial_\alpha f \partial_\beta f$
  δf: $\partial_\alpha(\sqrt{\eta}\eta^{\alpha\beta}\partial_\beta f) = 0 \equiv \eta^{AB}\partial_A\partial_B f = 0$
  δX^A: no new equations, $\Rightarrow X^A$ are undetermined functions of x, t, so 2 functions worth of Gauge!
- x, t arbitrary $\equiv$ general covariance
- So Hamiltonian theory has 2 constraints.
- **Remark:**Free sclar field solns are $f = f_+(T+X) + f_-(T-X)$
  Use split into "left movers + right movers" in Hamiltonian theory.

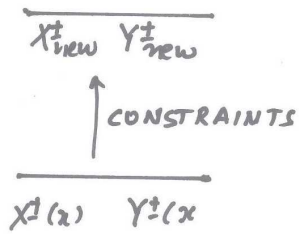
Hamiltonian description

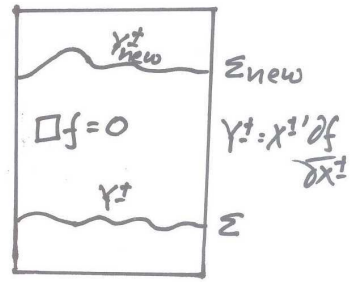
- $T(x), X(x)$ become canonical variables. Use light cone variables $T(x) \pm X(x) := X^{\pm}(x)$.
- Phase space: $(f, \pi_f), (X^+, \Pi_+), (X^-, \Pi_-)$
- Constraints: $H_{\pm}(x) \; = \; [\, \Pi_{\pm}(x) X^{\pm'}(x) \; \pm \; \frac{1}{4}(\pi_f \pm f')^2 \,]$
- Define: $Y^{\pm} = \pi_f \pm f'$
  $\{Y^+, Y^-\} = 0$, $\{Y^{\pm}(x), Y^{\pm}(y)\}$= derivative of delta function
- $\{H_+, H_-\} = 0$. P.B. algebra between smeared H_+'s isomorphic to Lie algebra of diffeomorphisms of Cauchy slice. Same for H_- algebra. $H_{\pm}$ generate evolution of $\pm$ fields. "Evolution $\equiv$ 2 independent diffeomorphisms"!
- Gauge fix: $X^{\pm} = t \pm x$ "deparameterize".
  get back standard flat spacetime free scalar field action.

Embeddings: $X(x), T(x) \equiv X^+(x), X^-(x)$



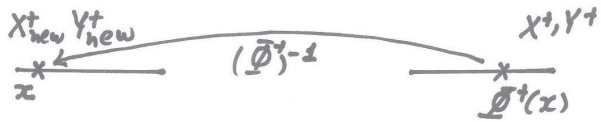
ACTION OF CONSTRAINTS:



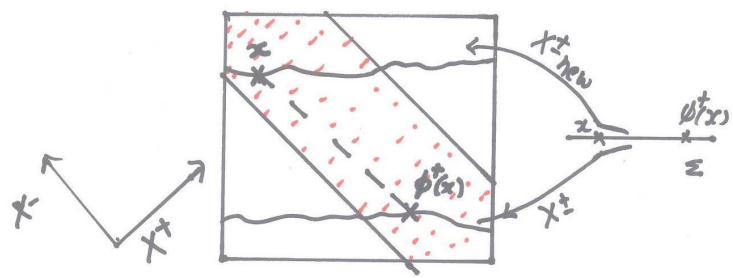


Y^{+}_{new}, X^{+}_{new} : Action of diffeo Φ^{+} on Y^{+}, X^{+}

Y^{-}_{new}, X^{-}_{new} : Action of diff-eo Φ^{-} on Y^{-}, X^{-}.



PLAUSIBLE... $f = f_{+}(x^{+}) + f_{-}(x^{-})$



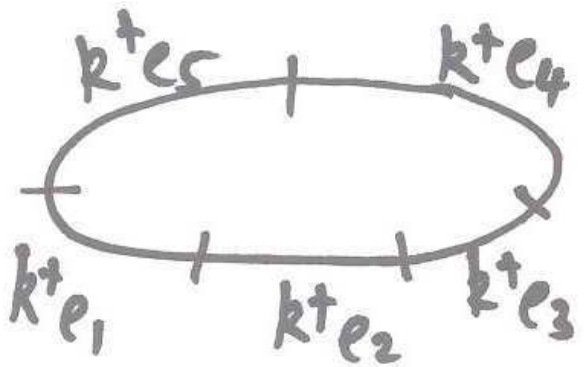
Caution:

- We set Spacetime Topology = $S^1 \times R$
- Not much known re:Polymer repn when space is non-compact. Hence choose space= circle.
- There are complications coming from using "single angular coordinate chart" x on embedded circle. Also from using single spatial angular inertial coordinate X on the flat spacetime. Identifications of x and X"mod 2π" are needed. These can be taken care of. Will mention subtelities as and when dictated by pedagogy.

Quantum Kinematics: Embedding Sector

- Holonomies:
  "Graph": set of edges which cover the circle.
  "Spins": a label k_e for each edge e.
  "Holonomies":$e^{i\sum_e k_e \int_e \Pi_+}$
- "Electric Field": $X^+(x)$
- Poisson Brkts: $\{X^+(x), e^{i\sum_e k_e \int_e \Pi_+}\} = ik_e e^{i\sum_e k_e \int_e \Pi_+}$
  (for x inside e)

- Charge Networks: $|\gamma, \vec{k}\rangle$



$\hat{X}^+(x)|\gamma, \vec{k}\rangle = \hbar k_e^+ |\gamma, \vec{k}\rangle$, x inside e.

$e^{i\sum_e \widehat{k_e'^+} \int_e \Pi_+} \; |\gamma, \vec{k}\rangle \; = \; |\gamma, \vec{k} + \vec{k}'\rangle$

Inner Product: $\langle \gamma', \vec{k}' | \gamma, \vec{k}\rangle = \delta_{\gamma',\gamma} \delta_{\vec{k},\vec{k}'}$

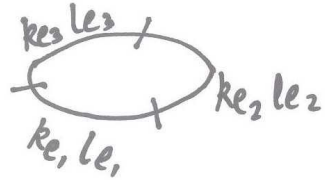
- Range of k_e: $\hbar k_e \in \mathbf{Z}a$, a is a Barbero- Immirzi parameter with dimensions of length.
- Similarly for $-$ sector.

Quantum Kinematics: Matter Sector and $\mathcal{H}_{kin}$

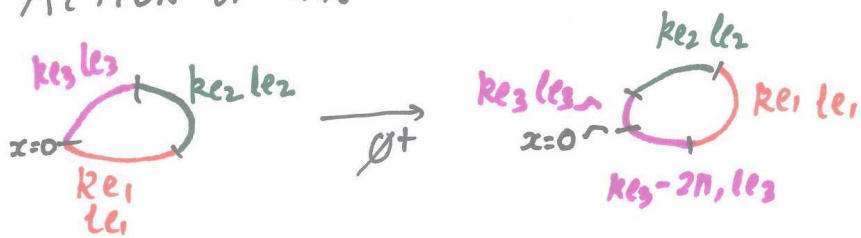
- Can define holonomies and repn on matter charge networks.
- Charge network: $|\gamma, \vec{l}\rangle$.
- $\mathcal{H}_{kin}$ obtained as product of $+, -$ embedding and matter charge nets.

- $\mathcal{H}_{kin} = \mathcal{H}^{+}_{kin} \otimes \mathcal{H}^{-}_{kin}$

  $\mathcal{H}^{\pm}_{kin} : |\gamma^{\pm}, \vec{k}^{\pm}, \vec{l}^{\pm}\rangle$



- ACTION OF GGE TRANSF: $\hat{U}(\phi^{+})|\gamma^{+}, \vec{k}^{+}, \vec{l}^{+}\rangle$



ϕ^{+} = diffeo + winding

l's move by diffeo along with edges

k's move with edges by diffeo but are augmented by "$2m\pi$"

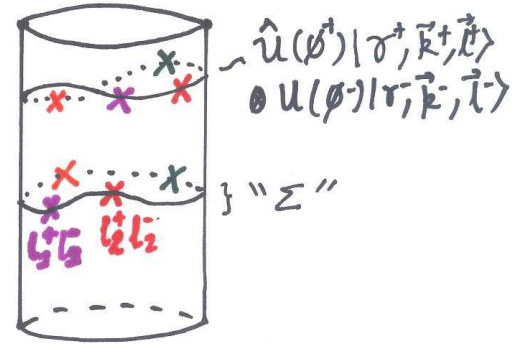
Physical Hilbert Space by Group Averaging

- Can construct physical states via grp avging w.r.to gge transformations just as we do for spatial diffeos in LQG.
- Grp Avg of a chrge net $|\gamma^+, \vec{k}^+, \vec{l}^+\rangle \otimes |\gamma^-, \vec{k}^-, \vec{l}^-\rangle$ is the distribution, $\sum \langle \gamma^+_{\phi^+}, \vec{k}^+_{\phi^+}, \vec{l}^+_{\phi^+}| \otimes \langle \gamma^-_{\phi^-}, \vec{k}^-_{\phi^-}, \vec{l}^-_{\phi^-}|$, where the sum is over all distinct gge related chrge nets.
- There is a nice geometrical interpretation for grp avge of a chrge net.

POLYMER STATES AND DISCRETE SPTIME:

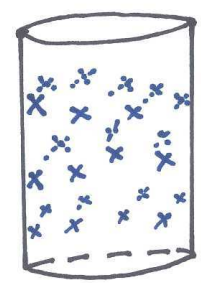
$$|\gamma^+, \vec{k}^+, \vec{l}^+\rangle \otimes |\gamma^-, \vec{k}^-, \vec{l}^-\rangle$$

$$(X^+, X^-) = (k^+, k^-)$$



GRP AVG : $\sum \langle \gamma^+_{\phi^+}, \vec{k}^+_{\phi^+}, \vec{l}^+_{\phi^+}| \otimes \langle \gamma^-_{\phi^-}, \vec{k}^-_{\phi^-}, \vec{l}^-_{\phi^-}|$

$$\{(k_1^+, k_1^-, l_1^+, l_1^-), (k_2^+, k_2^-, l_2^+, l_2^-) \ldots\}$$



DISCRETE SPTIME, each pt. $(X^+, X^-) = (k^+_i, k^-_i)$ is labelled by (l^+_i, l^-_i)

PFT dynamics a la LQG

- We follow Thiemann's seminal work:
  - Construct solutions to $C_{diff} := H_+ + H_-$ by group averaging w.r.to spatial diffeos.
  - $C_{ham} := \frac{H_+ - H_-}{\sqrt{X^{+\prime} X^{-\prime}}}$, define $\hat{C}_{ham}$ at finite triangulation.
  - Find its continuum limit on diffeomorphism invariant states
  - Evaluate its commutator and check for anomalies.

- Diffeo Averaging:
  - $C_{diff} = H_+ + H_-$.
  - Finite diffeo ϕ corresponds to the gauge transformations $\phi = \phi^+ = \phi^-$. ($\Rightarrow$ Physical states are diffeo invariant!)
  - Diff avg of a charge net is the sum over all its distinct diffeo images: $\sum \langle \gamma_\phi^+, \vec{k}_\phi^+, \vec{l}_\phi^+ | \otimes \langle \gamma_\phi^-, \vec{k}_\phi^-, \vec{l}_\phi^- |$
  - Diff related states define same discrete slice, data.

  Diff avg $\equiv$ single discrete slice.

  ($\Rightarrow$ Physical states NOT normalizable in $\mathcal{H}_{diff}$!)

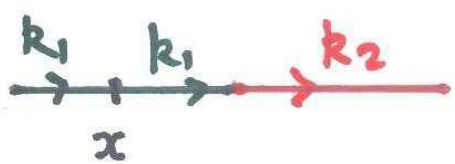
Hamiltonian constraint

Question:Can we construct $\hat{C}_{ham}$ s.t. it kills physical states we have just constructed?

- Define $\hat{C}_{ham,T(\delta)}|\mathbf{s}^+\mathbf{s}^-\rangle$.($\mathbf{s}^\pm \equiv \gamma^\pm, \vec{k}^\pm, \vec{l}^\pm$).
  Define state dep T s.t. every vertex of state is vertex of T. Let coordinate length of every edge (i.e. 1 cell) of T be δ.
- $\hat{C}_{ham,T} = \widehat{(H_+ + H_-)}|_T \widehat{\frac{1}{\sqrt{|X^{+\prime}X^{-\prime}|}}}_T$
- $\frac{1}{\sqrt{|X^{+\prime}X^{-\prime}|}}$ from P.B. of holonomies with spatial volume function $V(R) = \int_R dx\sqrt{|X^{+\prime}X^{-\prime}|}$. Can construct $\hat{V}(R)$ and replace PB by $[,]$.
- The resulting operator acts nontrivially only at vertices of the state: $\widehat{\frac{1}{\sqrt{|X^{+\prime}(v)X^{-\prime}(v)|}}}_T|\mathbf{s}^+\mathbf{s}^-\rangle = \delta\lambda(v)|\mathbf{s}^+\mathbf{s}^-\rangle$
  Overall factor of δ similar to LQG undensitized triad operator.
- Care needed to ensure that operator doesnt kill zero volume states else kernel of $\hat{C}_{ham}$ too large!

$H_+ \widehat{-} H_-|_T$

- $H := H_+ - H_- = \Pi_+ X^{+\prime} - \Pi_- X^{-\prime} +$ matter.
  H generates gge transf with $\phi^+ = \phi^{--1}$. Unitary repn of finite gge transf not weakly cont. How can we define $\hat{H}$?
- Key Idea: Try to write $\hat{H}_T$ proportional to $(\text{finite} \quad \widehat{\text{gge}} \quad \text{transf.} - \mathbf{1})$. Illustrate with $\Pi_+ X^{+\prime}$ term.
- $\hat{X}^{+\prime}(x)|_T |\mathbf{s}^+\mathbf{s}^-\rangle = \frac{\Delta_x k^+}{\delta} |\mathbf{s}^+\mathbf{s}^-\rangle$.



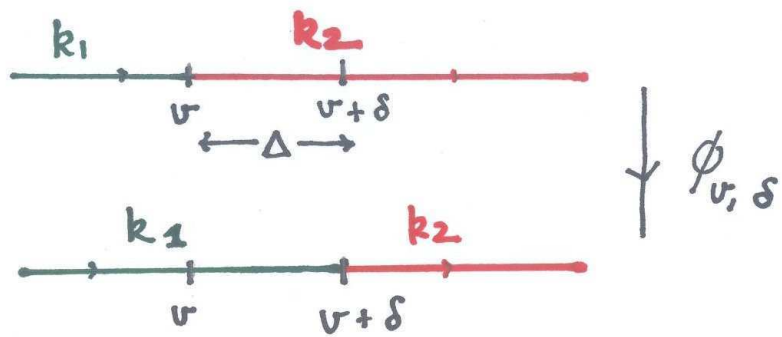
$\Delta_x k = k_1 - k_1 = 0$

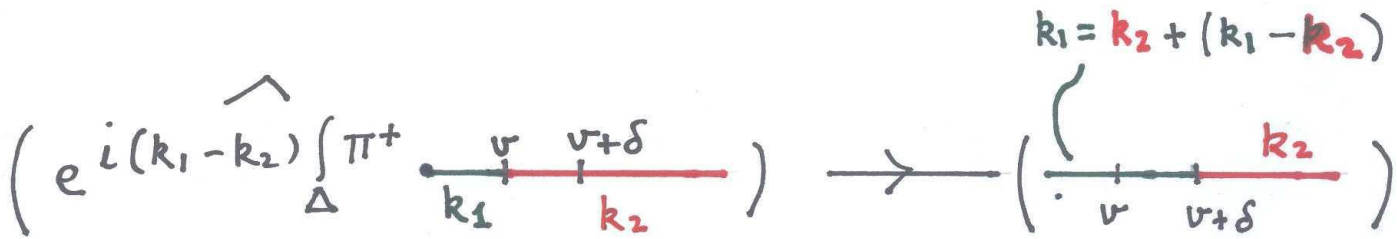
$\Delta_x k = k_2 - k_1$

" non-trivial vertex "

$\hat{\Pi}_+|_T$

- $\Pi_+|_T =$ " $\frac{\text{Edge holonomy}-1}{\delta}$ "
- What does a small, finite, gauge tranformation do?





- We define: $\hat{\Pi}_+|_T(v)|\mathbf{s}^+\mathbf{s}^-\rangle = \frac{e^{-i(\Delta_v k)\widehat{\int_\Delta \Pi_+}}-\mathbf{1}}{-i(\Delta_v k)\delta}|\mathbf{s}^+\mathbf{s}^-\rangle.$

$$\Rightarrow \hat{\Pi}_+|_T \hat{X}^{+\prime}|_T|\mathbf{s}^+\mathbf{s}^-\rangle = \frac{e^{-i\Delta_v k\widehat{\int_\Delta \Pi_+}}-\mathbf{1}}{-i\delta^2}|\mathbf{s}^+\mathbf{s}^-\rangle = \frac{\hat{U}_E^+(\phi_{v,\delta})-\mathbf{1}}{-i\delta^2}|\mathbf{s}^+\mathbf{s}^-\rangle$$

$\hat{C}_{ham}$

Recall that $H = \Pi_+ X^{+\prime} - \Pi_- X^{-\prime} +$ matter,
$C_{ham} = H(\sqrt{|X^{+\prime} X^{-\prime}|})^{-1}$

- Get: $\hat{H}_T(v)|\mathbf{s}^+\mathbf{s}^-\rangle = \frac{\hat{U}^+_{\phi_{v,\delta}} \otimes \hat{U}^-_{\phi_{v,-\delta}} - \mathbf{1}}{-i\delta^2}|\mathbf{s}^+\mathbf{s}^-\rangle$
  $\widehat{\frac{1}{\sqrt{|X^{+\prime} X^{-\prime}|}}}(v)|_T = \delta\lambda(v) \quad \int dx \to \sum_{\triangle \in T} \delta$
- $\hat{C}_{ham,T(\delta)}[N]|\mathbf{s}^+\mathbf{s}^-\rangle = \sum_v N(v)\lambda(v)(\hat{U}^+_{\phi_{v,\delta}} \otimes \hat{U}^-_{\phi_{v,-\delta}} - \mathbf{1})|\mathbf{s}^+\mathbf{s}^-\rangle$
  Finite operator as in LQG. Kills correct solutions at all $T(\delta)$!
- Continuum limit ala Thiemann: Let Ψ be spatially diffeo inv state. Can show
  $\lim_{\delta\to 0} \Psi(\hat{C}_{ham,T(\delta)}[N]|\mathbf{s}^+\mathbf{s}^-\rangle)$ exists exactly as in LQG.
  (Technically: Cont limit exists on $\mathcal{H}_{kin}$ in URS topology.)
- Can also show that commutator between 2 Ham constraint vanishes in this continuum limit.
- For RHS, need to construct spatial diffeo operator.

$\hat{C}_{diff}$

- $C_{diff} = \Pi_+ X^{+\prime} + \Pi_- X^{-\prime} +$ matter. Similar techniques yield
  $\hat{C}_{diff}|_T(v)|\mathbf{s}^+\mathbf{s}^-\rangle = \frac{\hat{U}^+_{\phi_{v,\delta}} \otimes \hat{U}^-_{\phi_{v,\delta}} - \mathbf{1}}{-i\delta^2}|\mathbf{s}^+\mathbf{s}^-\rangle = \frac{\hat{U}^{diff}_{\phi_{v,\delta}} - \mathbf{1}}{-i\delta^2}|\mathbf{s}^+\mathbf{s}^-\rangle$
- $\hat{C}_{diff}[\vec{N}]|_T(v)|\mathbf{s}^+\mathbf{s}^-\rangle = \sum_v N^x(v) \frac{\hat{U}^{diff}_{\phi_{v,\delta}} - \mathbf{1}}{-i\delta}|\mathbf{s}^+\mathbf{s}^-\rangle$
  NOT A FINITE OPERATOR.
- RHS has shift $\beta^x = q^{xx}(NM' - MN')$, $q^{xx} = (|X^{+\prime}X^{-\prime}|)^{-1}$
  $\hat{q}^{xx}_T(v) = (\widehat{\frac{1}{\sqrt{|X^{+\prime}X^{-\prime}|}}}(v)|_T)^2 \to \delta^2(\lambda(v))^2$
- $\hat{C}_{diff}[\vec{\beta}]|_T(v)|\mathbf{s}^+\mathbf{s}^-\rangle = i\delta \sum_v \lambda^2(NM' - MN')(v)(\hat{U}^{diff}_{\phi_{v,\delta}} - \mathbf{1})|\mathbf{s}^+\mathbf{s}^-\rangle$
  Thiemann Cont Limit of this operator vanishes "doubly"!
  -due to overal factor of δ
  -because diffeo inv states killed by $\hat{U}^{diff}_{\phi_{v,\delta}} - \mathbf{1}$
  exactly same structure in LQG!.

LM Habitat

- $C_{ham}[N]$ is not diff inv due to lapse. $\hat{C}_{ham}[N]$ does not map diff inv states to diff inv states hence need to interpret cont limit thru URST.
- Note that but for $N(v)$ factors, $\hat{C}_{ham}[N]$ "almost" maps diff inv states to diff inv states. L-M construct a space of "almost" diff inv distributions on which cont limit of $\hat{C}_{ham,T(\delta)}$ can be taken directly so that the space is mapped into itself by $\hat{C}_{ham}$.
- LM Habitat '$\mathcal{V}_{LM}$':
  -Let non trivial vertices of $|\mathbf{s}^+, \mathbf{s}^-\rangle$ be $v_1, ..., v_n$.
  -Let $f : (S^1)^n \to \mathbf{C}$. Let diffeo class of state be $[\mathbf{s}^+, \mathbf{s}^-]$.
  -Let $\Psi_{f,[\mathbf{s}^+,\mathbf{s}^-]} := \sum \langle \mathbf{s}^+_\phi, \mathbf{s}^-_\phi | f(\phi v_1, .., \phi v_n)$.
  $\mathcal{V}_{LM}$ is finite span of distrbtns of form $\Psi_{f,[\mathbf{s}^+,\mathbf{s}^-]}$.
- f are called 'vertex smooth' functions. (Note:If $f =$ const, get diffeo inv states.)

$\hat{C}_{ham}[N]$ and its commutator on $\mathcal{V}_{LM}$

- Can show that $\forall |\mathbf{s}^{+\prime}\mathbf{s}^{-\prime}\rangle$
  $\lim_{\delta\to 0} \Psi_{f,[\mathbf{s}^+,\mathbf{s}^-]}(\hat{C}_{ham,T(\delta)}[N]|\mathbf{s}^{+\prime}\mathbf{s}^{-\prime}\rangle) = \sum_i \Psi_{g_i,[\mathbf{s}^+{}_i,\mathbf{s}_i^-]}(|\mathbf{s}^{+\prime}\mathbf{s}^{-\prime}\rangle)$,
  i.e. continuum limit of constraint maps $\mathcal{V}_{LM}$ into itself.
- Can show that commutator of 2 smeared ham constraints vanishes.
- Can show RHS also vansishes i.e.
  $\lim_{\delta\to 0} \Psi_{f,[\mathbf{s}^+,\mathbf{s}^-]}(\widehat{C_{diff,T(\delta)}(\vec{\beta})}|\mathbf{s}^{+\prime}\mathbf{s}^{-\prime}\rangle) = 0$. Again, "doubly":
  -due to overall factor of δ
  - due to "$\hat{U}^{diff}_{\phi_{v,\delta}} - \mathbf{1}$", one obtains difference of evaluations of f at points which are seperated by δ.
- Could one get nontrivial action of RHS with extra factor of δ^{-2}?
  - one δ^{-1} to cancel overall δ
  - one δ^{-1} to convert difference of functions into derivative.
- Answer is YES! To see what happens, consider $\hat{C}_{diff}[N]$.

$\hat{C}_{diff}[\vec{N}]$ on $\mathcal{V}_{LM}$

- Recall $\hat{C}_{diff,T(\delta)}[\vec{N}] = \sum_v N^x \frac{\hat{U}^{diff}_{\phi_{v,\delta}} - \mathbf{1}}{-i\delta}$.
  $\lim_{\delta\to 0} \hat{C}_{diff,T(\delta)}[\vec{N}]\ \Psi_{f,[\mathbf{s}^+,\mathbf{s}^-]} = \Psi_{g,[\mathbf{s}^+,\mathbf{s}^-]}$ with
  $g =$ "$\mathcal{L}_{\vec{N}} f$" $:= \sum_i N^x(v_i) \frac{\partial f(v_1,..,v_n)}{\partial v_i}$.
- This action yields a faithful repn on $\mathcal{V}_{LM}$ of PB algebra of diffeo constraints.
  Lesson for LQG: Should be open to consideration of operators which do not have finite action on $\mathcal{H}_{kin}$.
- How can we get the 2 extra factors of δ^{-1} in commutator of 2 Ham constraints in PFT?
  Answer: By using density 2 Ham constraint $H = \sqrt{q} C_{ham}$ instead of density 1 C_{ham}.
  $\{H(N), H(M)\} = C_{diff}(\mathcal{L}_{\vec{N}} \vec{M})$, $N, M \equiv \vec{N}, \vec{M}$.
- Due to extra δ^{-1}, cont lim of $\hat{H}_{T(\delta)}$ on $\mathcal{V}_{LM}$ blows up. Its commutator is also ill defined. $\Rightarrow$ "Anomaly" on LM habitat.

$\hat{H}, \hat{C}_{diff}$ on New Habitat $\mathcal{V}_{+-}$

(Slick, quick argument for anomaly free density 2 constr algebra on $\mathcal{V}_{+-}$.)

- Recall $H_\pm$ generate action of $\phi^\pm$ on phase space. $\phi^\pm$ are basically diffeos.
- Define $\mathcal{V}_+$ as LM type habitat for `+' sector "$\sum \langle \mathbf{s}^+_\phi | f(\phi^+ v^+_1, .., \phi^+ v^+_n)$" (v^+_i are vertices of $|\mathbf{s}^+\rangle$). $\hat{H}_+[N^+]$ acts as "Lie derivative" wrto $\vec{N}^+$.
- Get repn of $\{H_+[N^+], H_+[M^+]\}$ on $\mathcal{V}_+$. Similarly for `-'
- Define $\mathcal{V}_{+-} = \mathcal{V}_+ \otimes \mathcal{V}_-$. Since +,- sectors commute and $H = H_+ - H_-, C_{diff} = H_+ + H_-$, get anomaly free repn of their constr algebra as well.

Discussion:PFT ideas to consider for LQG

- Consider pbility of allowing repns of holonomies at finite T to be state dependent.
- The lack of weak continuity of operators on $\mathcal{H}_{kin}$ are not necessarily a hindrance to the defn of their generators on an appropriate space of distributions thru mechanisms of finite T and continuum limit of dual action.
- The choice of density one constraints hides the underlying non- triviality of the constraint algebra; choice of more "singular" operators of higher density weight may be necessary to probe the constraint algebra.
- Key issue: Can we handle algebra of higher density constr in LQG?
  Call the commutator of 2 Ham constraints the 'LHS'.
  Call the oprtr correspondent of PB brkt between them, the 'RHS'.

RHS

- In PFT, for density 1 case, RHS vanishes in Thiemann URST as well as on LM habitat. In LQG density one results are same as for PFT (T-L-M-G-P). In PFT, density 2 constraints yield diffeo smeared by c- number vector field; not kinematically finite but well defined on LM.
- Question: Can we define the diffeo constraint smeared with c- number shift in LQG? Can check opertr at finite T is NOT finite (exactly by one power of δ^{-1} as in PFT). Is it definable on LM habitat? More precisely, does there exist a defn of $\hat{F}^i_{ab}|_T$ s.t. in continuum limit, $\hat{C}_{diff}[N]$ is defined on LM habitat and its commutator algbera isomorphic to Lie algebra of v.f.s? Looks like answer may be YES! (Work in progress, AL-MV).

LHS

- Question: For RHS to have net factor of δ^{-1} as in $\hat{C}_{diff,T(\delta)}[N]$ how should we rescale Ham constraint in LQG?
  Answer: Can check that we need to rescale it by $q^{\frac{1}{6}} \sim \delta^{-1}$.
- But:Rescaled constraints not well defined on LM habitat. How do we look for new habitat? Is there analog of Zero Volume habitat of PFT?
- GLMP rescale ham constraints by hand and show that cant get diffeo from commutator unless Ham constr moves vertices around. AL-MV diffeo constraint work should feed into this.