What Can Generalized Symmetries Do For You?

Seth Koren

University of Chicago 20-23 -> University of Notre Dame 23-26

Based on

2204.01741, 2204.01750

2211.07639 with Clay Córdova, Sungwoo Hong, Kantaro Ohmori

2212.13193 with Clay Córdova

Want to understand notions of global symmetries for extended operators

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Familiar global symmetries acting on local operators

$$\psi(x) \to e^{i\alpha Q}\psi(x)$$

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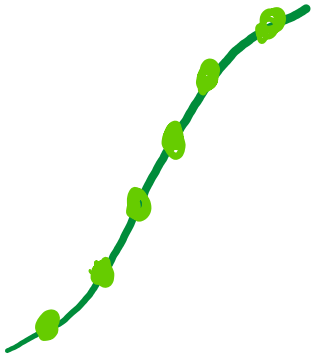
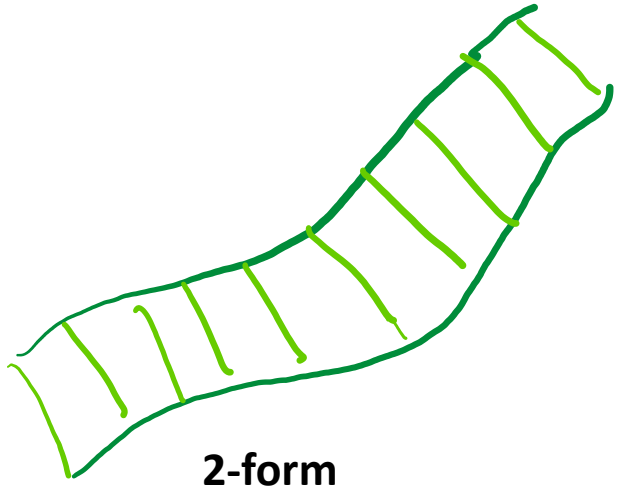
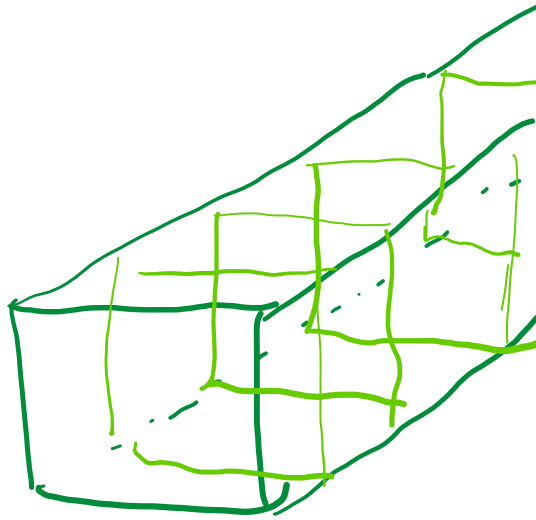
e.g. particles



1-form
line operators
e.g. Wilson line



2-form
surface operators
e.g. cosmic string



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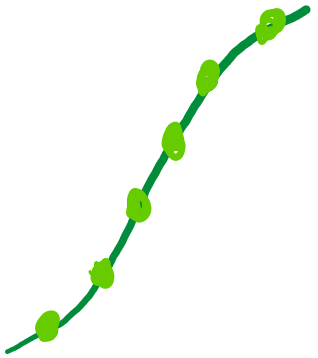

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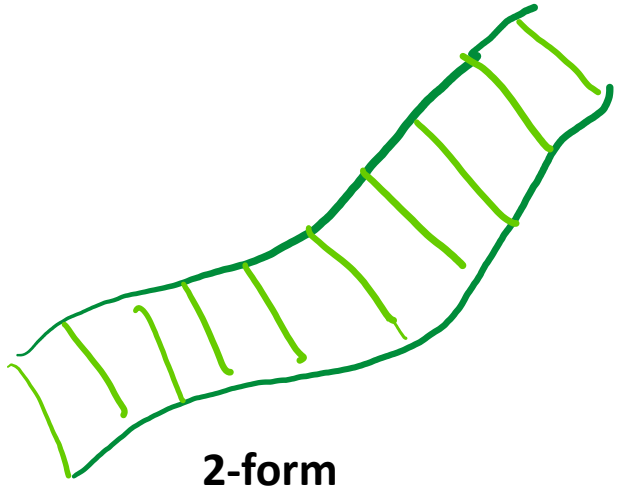

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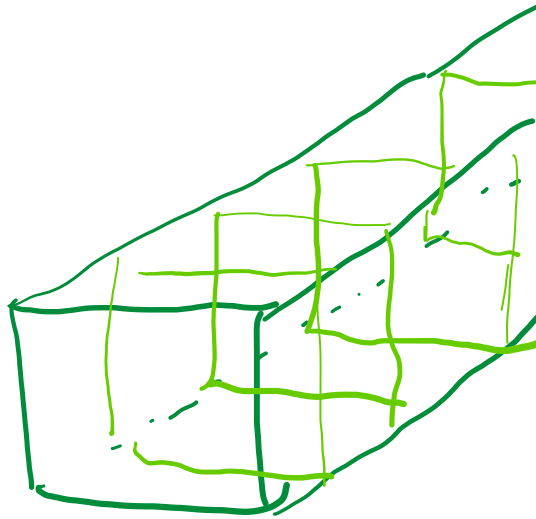

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Broken by local operators in Lagrangian
E.g. $\delta\mathcal{L}(x) = m_N NN$

Breaking requires modification of dof!

What sorts of things do we want to do that this could help us with?

Organize information from the infrared theory about the effects and possibilities of ultraviolet physics

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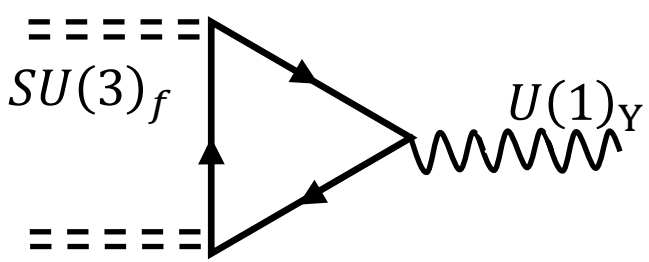
With $y_i \to 0$,
SM has $SU(3)^5$



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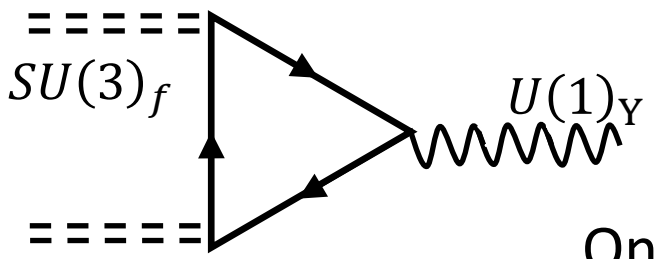

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If 1-form symmetry broken by providing monopoles $G \to G_{SM}$

Only 4 UV flavor patterns

$\{L, d\}$ $\{L, Q\}$ $\{L, e\}$
$\{Q, u, e\}$ $\{u, d, e\}$ $\{Q, u, d\}$

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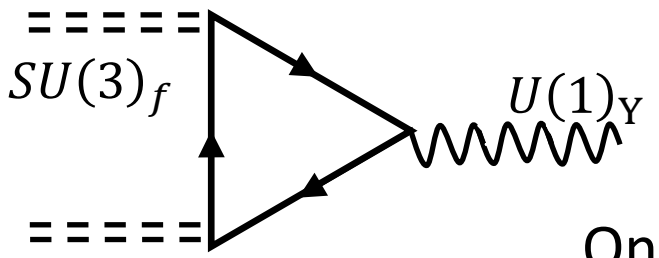

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Actual SM has $y \neq 0$ so 0-form flavor symmetries approximate

y is a spurion for the two-group structure

How? Controls the mass of new dof!

How can one generally understand this higher spurion analysis from the bottom up?

What does this have to say about gauge-flavor unification?

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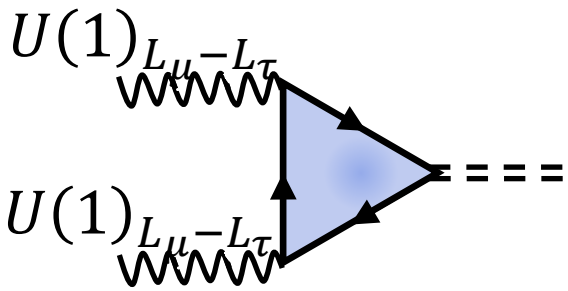
Another interplay of the magnetic 1-form symmetry with the 0-form symmetries



Noninvertible symmetries (among other uses) classify when instanton effects in a UV theory could generate small violation of some symmetry

$$\int F\tilde{F} \sim \int E \cdot B \neq 0$$

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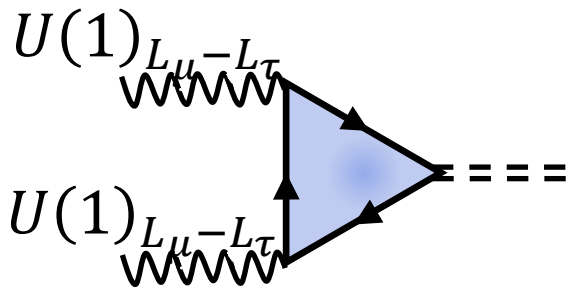

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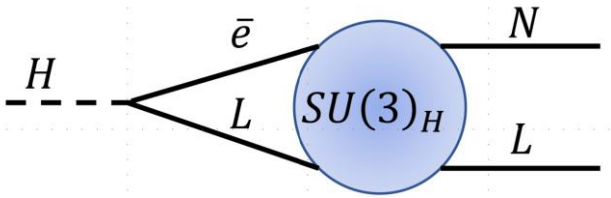
$U(1)_{L_\mu - L_\tau} \subset SU(3)_H$
Horizontal lepton symmetry



$$\mathcal{L} \sim y_\tau e^{-\frac{2\pi}{\alpha_H}} \tilde{H}\mathbf{LN}$$

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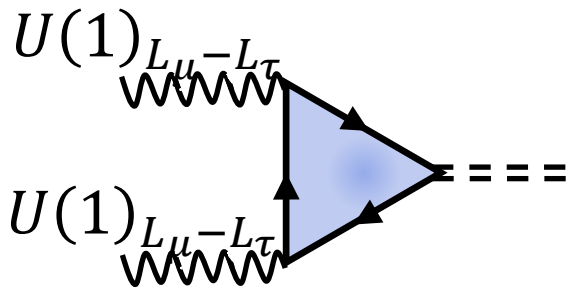

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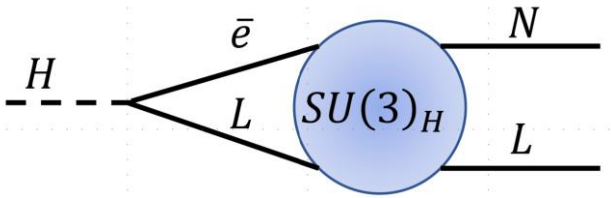

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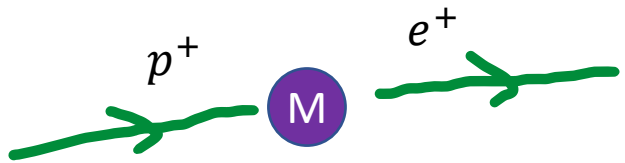
Have we already discovered all the interesting models where instantons generate naturally small parameters? No!

Learn about some new physical phenomena

Want to understand anomalous violation of global symmetries in the presence of topological defects



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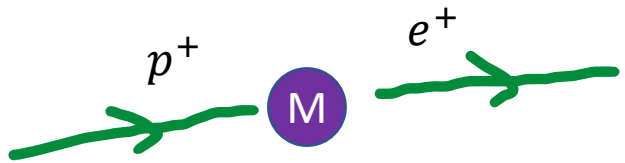

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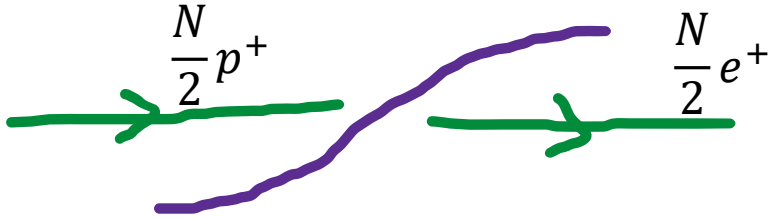
Gauged $U(1)_{B-L} \to Z_N$ has cosmic strings with similar effects



For $N = 6$, cosmological lithium problem
In general, minimal extension of SM

Need to understand BF theory with light fermions

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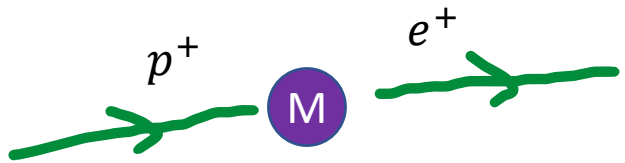

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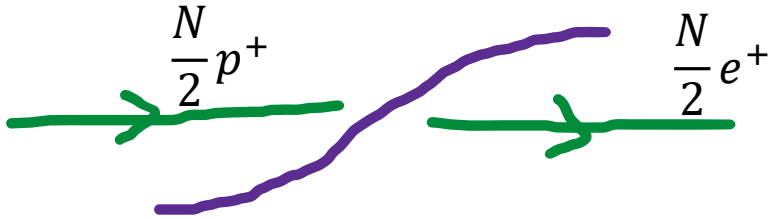

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We’ve long appreciated that you’re `activating’ the anomaly in the monopole core $\Delta Q \propto \int \vec{E} \cdot \vec{B}$
Noninvertible symmetries to precisely describe Callan-Rubakov (Komargodski et al. ‘23?)

See also Brennan, Hong, Wang 2302.00777, axion cosmic strings can have interesting interplay with dark Abelian Higgs sectors
Also McNamara, Reece & Asadi, Homiller, Lu, Reece 2212.03882 on Higgsed CP and domain walls

Conclusions

- Models you care about have generalized symmetries
- Understanding the generalized symmetries offers insight into UV completions, model-building opportunities, and the fascinating physics of topological defects
- What more do we have to learn from subtler notions of symmetries in field theories?