Generalized Global Symmetries in QFTs via String Compactifications

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State of the Field

Higher-Form Symmetries:

- Foundation: [Gaiotto, Kapustin, Seiberg, Willett 2014], [Aharony, Seiberg, Tachikawa 2013]
- Low-d Theories: [Aharony, Benini, Cordova, Hsin, Gaiotto, Kapustin, Komargodski, Lam, Ohmori, Razamat, Seiberg, Shao, Thorngren, Willett, $\cdots$]
- In String Theory: [Garcia Etxebarria, Heidenreich, Regalado 2019], [Eckhard, Kim, Schafer-Nameki, Willett 2019], [Morrison, Schafer-Nameki, Willett 2020], [Albertini, Del Zotto, Garcia Etxebarria, Hosseini 2020]
- Floodgates Opened: [Apruzzi, Beest, LB, Bonetti, Closset, Cvetic, Del Zotto, Dierigl, Garcia Etxebarria, Giacomelli, Gould, Heckman, Hubner, Hosseini, Lin, Meynet, Morrison, Moscrop, Schafer-Nameki, Wang, Zhang, $\cdots$]

State of the Field

Higher-Group Symmetries:

- Foundation: [Tachikawa 2017], [Cordova, Dumitrescu, Intriligator 2018], [Benini, Cordova, Hsin 2018]
- In String Theory: [Apruzzi, LB, Oh, Schafer-Nameki 2021], [LB 2021]
- Lots of Activity: [Apruzzi, LB, Cordova, Cvetic, Del Zotto, DeWolfe, Dumitrescu, Garcia Etxebarria, Gould, Heckman, Hidaka, Higginbotham, Hsin, Hubner, Intriligator, Iqbal, Lam, Lee, Nitta, Ohmori, Poovuttikul, Schafer-Nameki, Tachikawa, Torres, Yokokura, $\cdots$]

State of the Field (Future)

Non-Invertible/Higher-Categorical Symmetries:

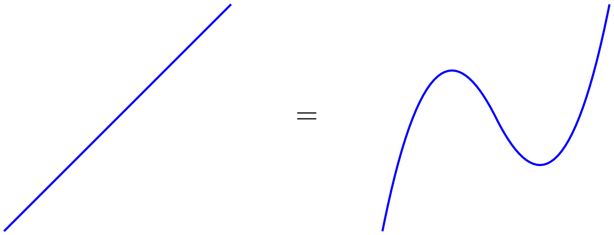
- Low-d: [Fuchs, Gaberdiel, Runkel, Schweigert early 2000s], [Barkeshli, Bonderson, Cheng, Wang 2014], [LB, Tachikawa 2017], [Chang, Lin, Shao, Wang, Yin 2018]
- High-d: [Heidenreich, McNamara, Montero, Reece, Rudelius, Valenzuela 2021], [Koide, Nagoya, Yamaguchi 2021], [Choi, Cordova, Hsin, Lam, Shao 2021], [Kaidi, Ohmori, Zheng 2021], [Roumpedakis, Seifnashri, Shao 2022], [LB, Bottini, Schafer-Nameki, Tiwari 2022], [Hayashi, Tanizaki 2022], [Arias-Tamargo, Rodriguez-Gomez 2022], [Choi, Cordova, Hsin, Lam, Shao 2022]
- In String Theory: [Future Direction]

What is it Good for?

- Standard (IR) Answer: Constrains low-energy physics, phase structure.
- Not a satisfactory answer for high-d theories.
- Alternative (UV) Answer: Encodes information about the spectrum of extended defects and local operators. Note: Non-topological!

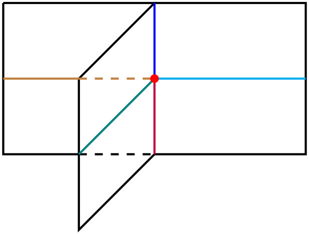
General Generalized Symmetries :)

- Existence of topological defects:



General Generalized Symmetries

- Complicated junctions of topological defects:

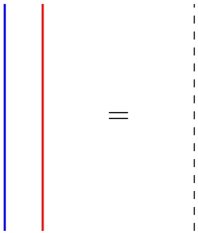


- All of this encoded in the structure of a **higher-category**.

[LB, Bottini, Schafer-Nameki, Tiwari 2022]

Higher-form Symmetries

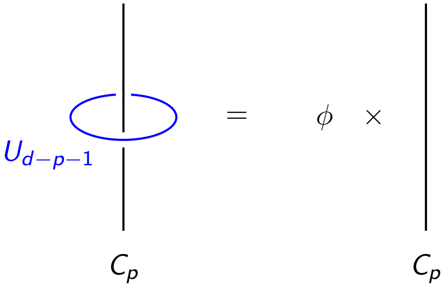
- Topological defects having inverses:



- Codimension-1 $\implies$ 0-form symmetry.
- Codimension-$(p+1)$ $\implies$ p-form symmetry.

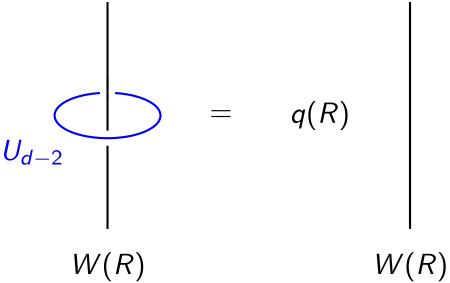
Charged Objects

- Charged objects have dimension-p:



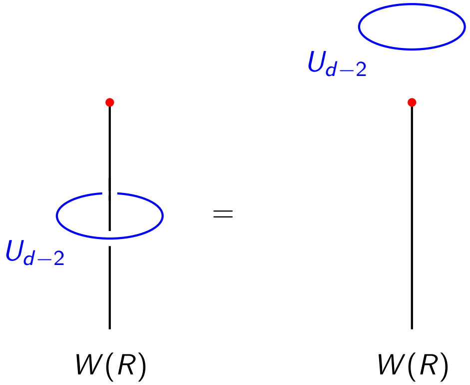
Electric 1-Form Symmetries: Pure Gauge Theory

- Gauge group G with center $Z(G)$.
- Gukov-Witten operators valued in $Z(G)$.

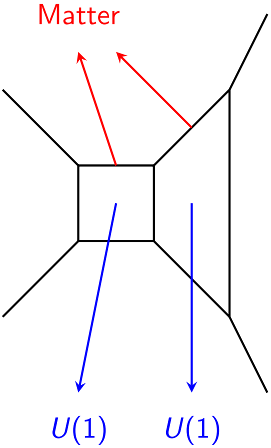


Electric 1-Form Symmetries: Matter Included

- Matter charged in representation R of G.

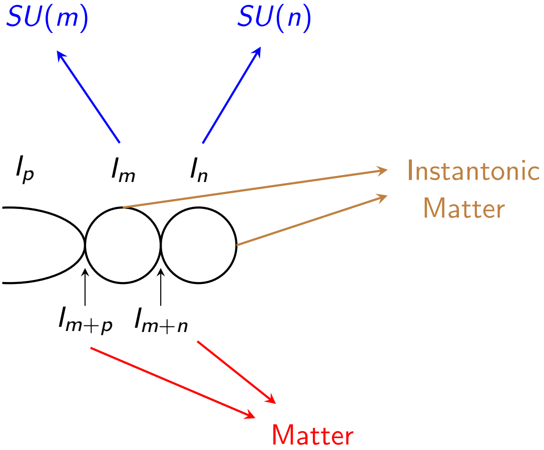


1-Form Symmetries: 5d SCFTs



[LB, Schafer-Nameki 2020]

1-Form Symmetries: 6d SCFTs



[LB, Schafer-Nameki 2020]

1-Form Symmetries: More General Scenarios

- Type IIB on CY3 $\longrightarrow$ Argyres-Douglas Theories
- $6d$ $\mathcal{N} = (2, 0)$ Theories $\longrightarrow$ $4d$ $\mathcal{N} = 2$ Class S Theories

Electric 1-Form Symmetries: Restated

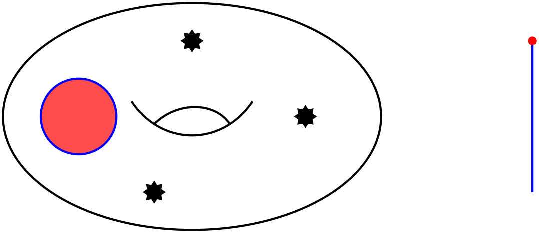
- Wilson Line Reps modulo Matter Reps $\longrightarrow$ Electric 1-form Symmetry.
- Line Defects modulo Screenings (Local operators living at ends) $\longrightarrow$ 1-form Symmetry.
- p-dimensional Defects modulo Screenings ($p-1$ dimensional operators living at ends) $\longrightarrow$ p-form Symmetry.

Higher-Form Symmetries in String Theory

- Defects $\longleftrightarrow$ Non-Compact Cycles.
- Screenings (Dynamical Objects) $\longleftrightarrow$ Compact Cycles.
- Higher-form Symmetries $\longleftrightarrow$ Relative Homology $H_*(X, \partial X)$.

  [Morrison, Schafer-Nameki, Willett 2020], [Albertini, Del Zotto, Garcia Etxebarria, Hosseini 2020]

1-Form Symmetries: Class S

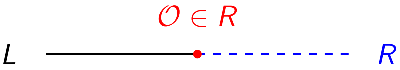


- 6d $\mathcal{N} = (2,0)$ theory of type G has $Z(G)$ surface defects modulo screenings.
- Closed 1-Cycles $\longleftrightarrow$ Line Defects.
- Exact 1-Cycles $\longleftrightarrow$ Screenings.
- Homology $H_1\big(\Sigma, Z(G)\big) \longleftrightarrow$ 1-form Symmetry.

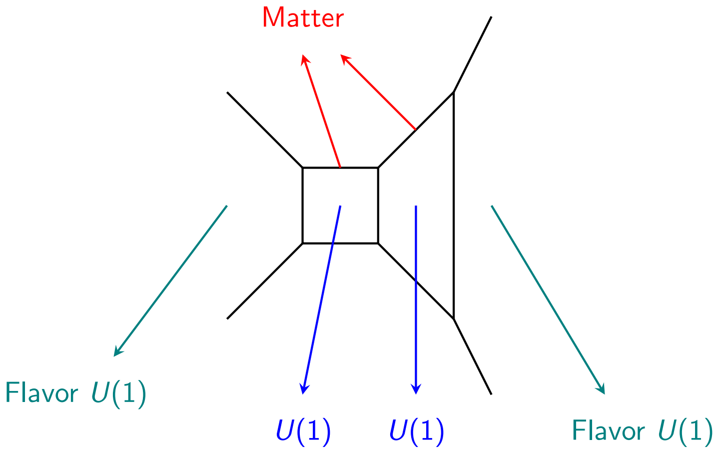
[LB, Hubner, Schafer-Nameki 2021], [LB, Giacomelli, Hubner, Schafer-Nameki 2021]

2-Group Symmetries

- 1-form Symmetry $\longleftrightarrow$ Line Defects modulo Screenings.
- 2-group Symmetry $\longleftrightarrow$ (Line Defects, Flavor Wilson Lines) modulo (Screenings with Flavor Charges Accounted).

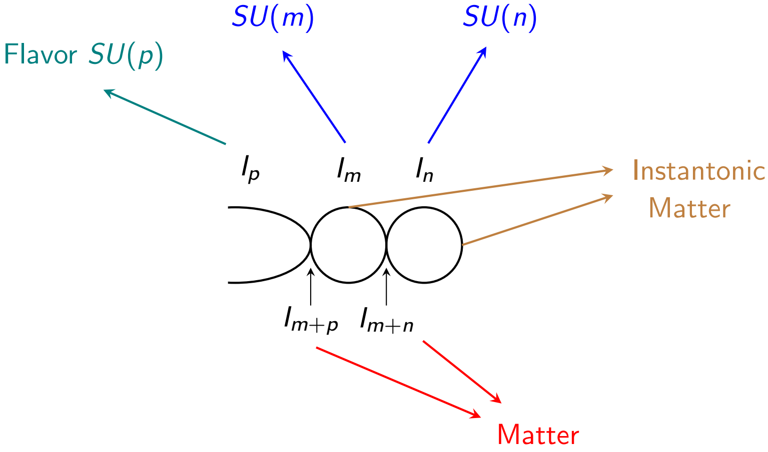


2-Group Symmetries: 5d SCFTs



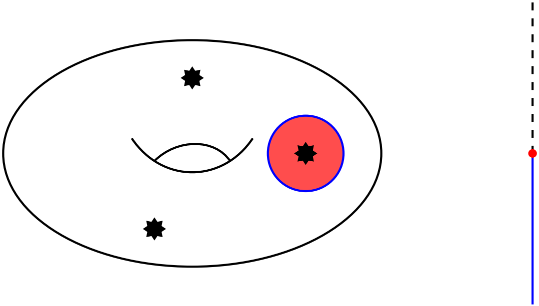
[Apruzzi, LB, Oh, Schafer-Nameki 2021]

2-Group Symmetries: $6d$ SCFTs



[Apruzzi, LB, Gould, Schafer-Nameki 2021]

2-Group Symmetries: Class S



[LB 2021]

Summary

- Rapidly evolving field:
  Higher-form $\longrightarrow$ Higher-group $\longrightarrow$ Higher-categorical
- Higher-form and higher-group symmetries known to capture deep **UV properties** regarding spectrum of extended defects and local operators.
- Can be computed for non-Lagrangian theories using string and partial-string compactifications.

Thank you for your attention!