Emergent SUSY in 2d

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Background

Regardless of many efforts, SUSY has not been observed yet. This fact may teach us we had better change our approach. Then,

- Don't you think if a suitable deformation of non-SUSY theory manifests the symmetry in IR, we could discover SUSY in a lab?
- Isn't it nice if we have new constraints on RG flow?
- What if the constraint works even on non-Lagrangian theory?

We did these; we found an RG flow from $\mathcal{N}=0$ UV (non-Lagrangian) theory to $\mathcal{N}=(1,1)$ IR theory in 2d, and showed it analytically and numerically.

Constraints on RG flow

Our UV theory is the fermionic $m=5$ minimal model with central charge $c=4/5$. It is non-SUSY, and has 10 primaries. The theory has (generalized) symmetries generated by 10 topological defect lines (TDLs), 2 invertible and 8 non-invertible:

NS-NS	id	$\sigma'\bar{\sigma}'''$	$\lvert\epsilon''\rvert^2$	$\sigma'''\bar{\sigma}'$	$\lvert\epsilon''''\rvert^2$	$\lvert\epsilon'\rvert^2$	$\sigma\bar{\sigma}''$	$\lvert\epsilon\rvert^2$	$\sigma''\bar{\sigma}$	$\lvert\epsilon'''\rvert^2$
$\widehat{(-1)^F}$	1	-1	1	-1	1	1	-1	1	-1	1
$\hat{M}$	2	0	-1	0	2	2	0	-1	0	2
$\hat{W}$	ζ	ζ	ζ	ζ	ζ	$-\zeta^{-1}$	$-\zeta^{-1}$	$-\zeta^{-1}$	$-\zeta^{-1}$	$-\zeta^{-1}$
$\hat{N}$	$\sqrt{3}$	1	0	-1	$-\sqrt{3}$	$-\sqrt{3}$	-1	0	1	$\sqrt{3}$

Actions of TDLs on primaries in NS-NS sector $(\zeta := \frac{1+\sqrt{5}}{2})$

A relevant operator $\lvert\epsilon''\rvert^2$ triggers an RG flow. It preserves 4 TDLs $\{1,(-1)^F,W,(-1)^F W\}$. The surviving TDLs constrain the RG flow:

1) Since a non-invertible line W has quantum dimension $\zeta \notin \mathbb{N}$, IR theory cannot be trivial:

$\Rightarrow$ CFT, or TQFT w/ ground state degeneracy $\in 2\mathbb{N}$.

2) In CFT scenario, the c-theorem allows bosonic and fermionic $m=3,4$ minimal model, but $m=3$ theories are ruled out because they have no TDLs with quantum dimension ζ.

New constraint

If relevant operators are (spacetime) scalars, they preserve rotation symmetry. Thus its quantum numbers (spins) are conserved.

For a surviving TDL L, there is an associated defect Hilbert space $\mathcal{H}_L$. Operators of $\mathcal{H}_L$ have specific spins, called spin contents S_L.

Combining these facts, we arrive a new constraint

$$S_L^{\text{IR}} \subset S_L^{\text{UV}}.$$

The set in IR is a subset because some operators may be lifted along the RG flow.

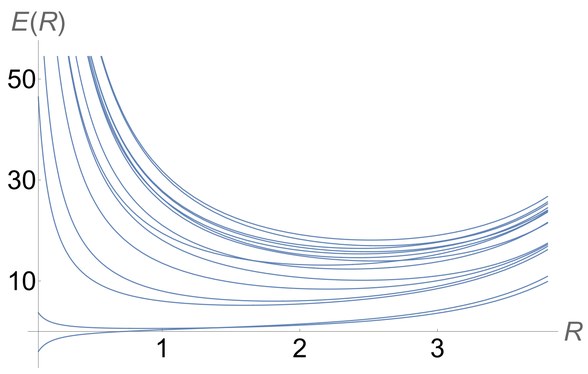
3) In CFT scenario, bosonic $m=4$ is ruled out because $\{0,\pm\frac{1}{2}\} = S^{m=4}_{\mathbb{Z}_2}$ boson. $\not\subset S^{m=5}_{\mathbb{Z}_2}$ fermion. $=\{0\}$.

$\Rightarrow$ The only possible IR CFT is $m=4$ fermionic model with $\mathcal{N}=(1,1)$ SUSY.

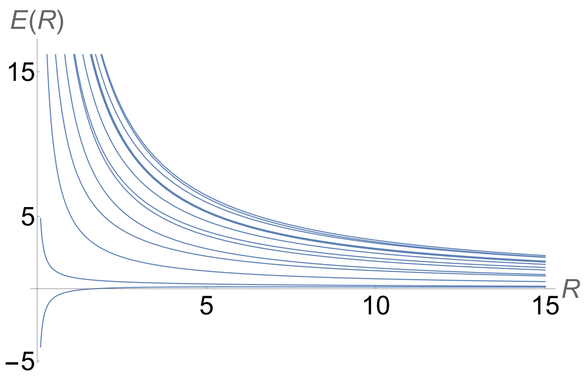
$$\therefore \textbf{IR theory} = \begin{cases} m=4 \textbf{ fermionic CFT} & (\textbf{GSD}=1) \\ \textbf{TQFT} & (\textbf{GSD}\in 2\mathbb{N}) \end{cases}$$

Numerical constraint

To fix ground state degeneracy (GSD), we employ numerical method called truncated conformal space approach.



Relevant coupling >0



Relevant coupling <0

In IR (large R), we see

$$\text{GSD} = \begin{cases} 1 & (\text{coupling} > 0) \\ 2 & (\text{coupling} < 0) \end{cases}.$$

We conclude $+\lvert\epsilon''\rvert^2$ triggers an RG flow with emergent SUSY

$$\begin{array}{c} m=5 \textbf{ fermionic minimal model w/} \mathcal{N}=0 \\ \downarrow \\ m=4 \textbf{ fermionic minimal model w/} \mathcal{N}=(1,1) \end{array}.$$