The Parisi-Sourlas Uplift & Infinitely Many Solvable CFT$_4$

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ENS Summer Institute

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Main Idea

$\underline{CFT_d} \xrightarrow{\text{uplift}}$ $\underline{CFT_{d+2}}$ with $\underline{\text{Parisi-Sourlas (PS) SUSY}}$

Context

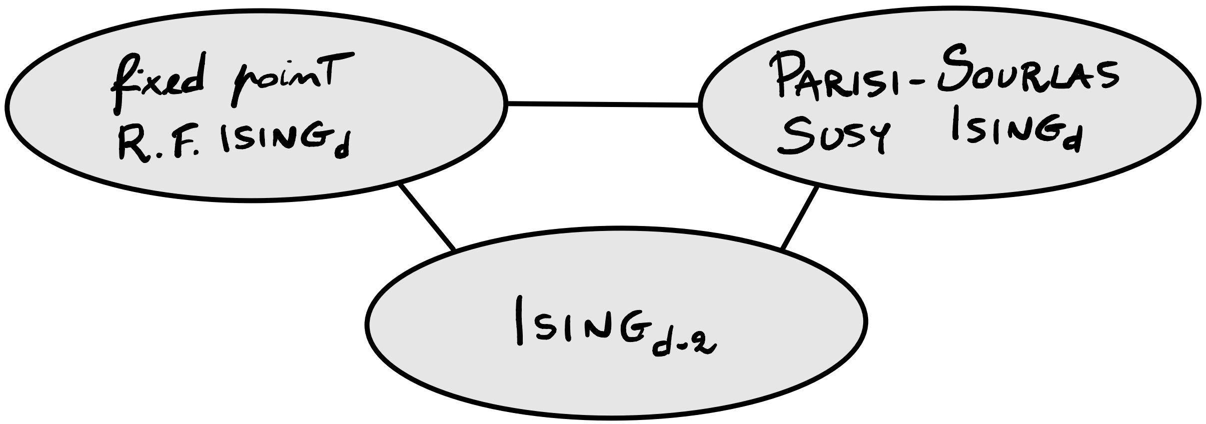
Random Fields (R.F.)
$\longrightarrow$ Impurities

Parisi-Sourlas Conjecture

Dimensional Reduction

CONTEXT

P.S. CONJECTURE [PARISI, SOURLAS '79]



R.F. ϕ^4 (ISING) $\to$ $d = 3,4$ ✗

$2 < d < 6$ $\to$ $d = 5$ ✓

[FYTAS, MARTIN MAYOR, PARISI, PICCO, SOURLAS]

R.F. ϕ^3 $\longrightarrow$ $\forall\, d$ ✓

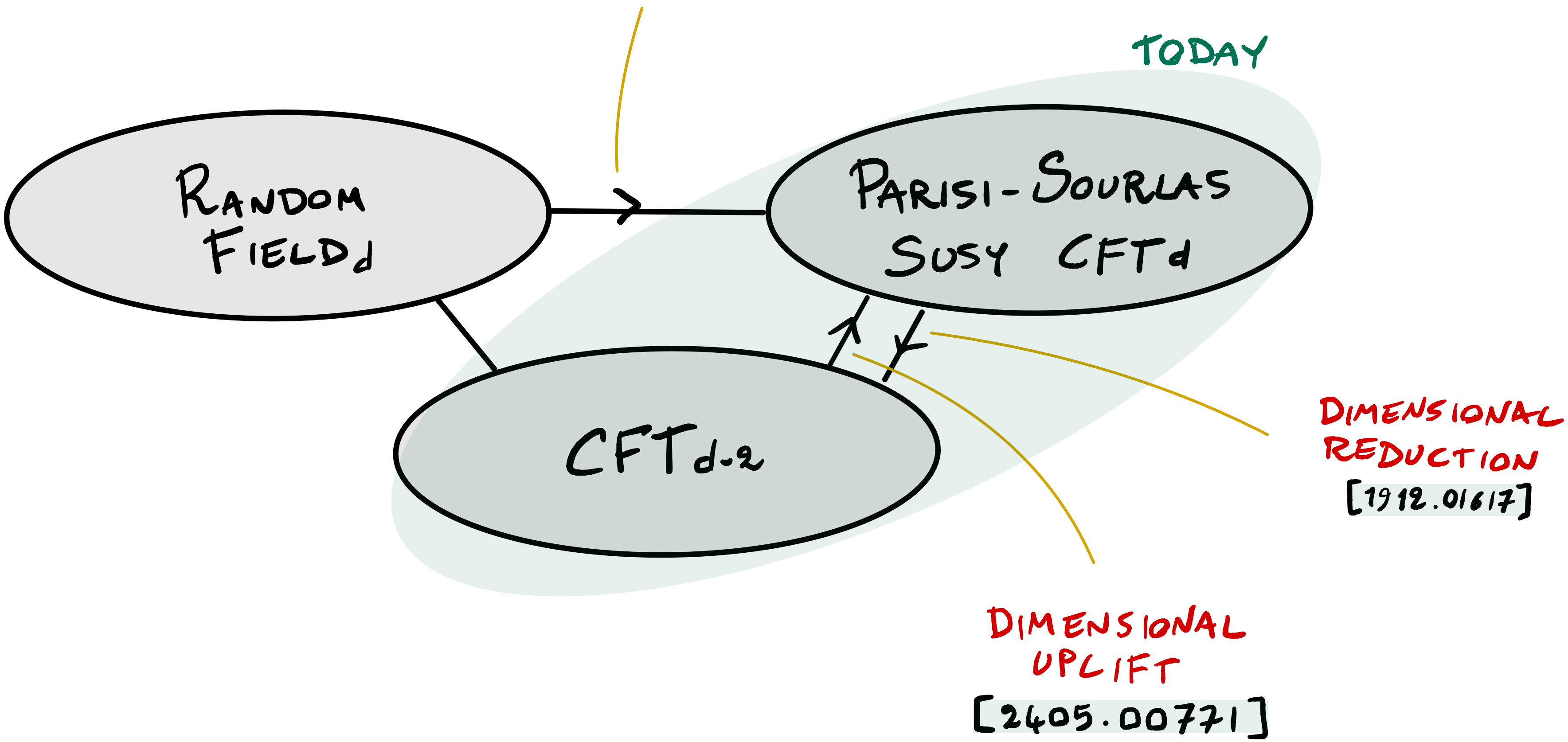
$2 \leq d < 8$

Q: when/why the conjecture works?

Upshot of the Results

[2009.10087]
[2112.06942]
[2203.12629]

EMERGENCE of SUSY
PERTURB. R.G. for RF ϕ^4, RF ϕ^3 } SUSY F.P. SOMETIMES UNSTABLE



MOTIVATIONS for UPLIFT

- ITERATED UPLIFT $\quad CFT_d \to PS\ CFT_{d+2} \to PS^2\ CFT_{d+4} \to \ldots$
- defines SOLVABLE $CFT_{d>2}$ by uplifting solvable CFT_2
  [e.g. minimal models]
- UPLIFTED MODELS are PHYSICAL
  [e.g. UPLIFTED LEE-YANG MIN. MOD. $\sim$ BRANCHED POLYMERS in $d=4$]
- SUSY as a Tool
  [e.g. use SUSY of the PS CFT_{d+2} to solve a question of CFT_d]
- KINEMATICAL RELATIONS $\quad CFT_d \leftrightarrow CFT_{d+2}$
  [e.g. relations on CONFORM. BLOCKS]

$\boxed{\text{OUTLINE}}$

UPLIFT

PS CFT

PS REDUCT. / UPLIFT

STRUCTURAL CHECK of UPLIFT

APPLICATIONS

BOOTSTRAP GENER. FREE FIELD (GFF) THEORY

DEFINE SOLVABLE $CFT_{d>2}$

PS CFT

$\boxed{\text{PS } CFT_d}$

SYMMETRIES: P^a TRANSL. L^{ab} ROTATION D DILATION K^a SPECIAL CONF. TR.

USUAL CFT_d : $a = 1, \dots d \longrightarrow SO(d+1,1)$

P.S. CFT_d : $a = 1, \dots d, \theta, \bar{\theta} \longrightarrow OSp(d+1,1|2) \subset SO(d+1,1) \times \underbrace{Sp(2)}_{\text{R-SYM}}$

$$\text{e.g.} \begin{cases} P^\theta = \partial^\theta \\ L^{\theta\mu} = \theta\,\partial^\mu - x^\mu \partial^\theta \end{cases}$$

$\theta, \bar{\theta}$: ANTICOMMUTING SCALARS

NO SPINORIAL CHARGES $\cancel{Q^\alpha}$ $\longrightarrow$ VIOLATES SPIN-STATISTICS $\longrightarrow$ NON UNITARY

OPERATORS

$\mathcal{O}(y)$ SUPER PRIMARY LABELLED BY $\begin{cases} \Delta \to D \\ \underset{\text{SPIN}}{Osp(d|2)} \to L^{ab} \end{cases}$

$y^a = (x^\mu, \theta, \bar{\theta}) \in \mathbb{R}^{d|2}$

COMPONENTS

$$\underset{\Delta}{\mathcal{O}^{a_1 \cdots a_\ell}(y)} = \underset{\Delta}{\mathcal{O}_0^{a_1 \cdots a_\ell}(x)} + \theta \underset{\Delta+1}{\mathcal{O}_{\bar{\theta}}^{a_1 \cdots a_\ell}(x)} + \bar{\theta} \underset{\Delta+1}{\mathcal{O}_{\theta}^{a_1 \cdots a_\ell}(x)} + \theta\bar{\theta} \underset{\Delta+2}{\mathcal{O}_{\theta\bar{\theta}}^{a_1 \cdots a_\ell}(x)}$$

$Osp(d|2)$ irreps. $\longrightarrow$ $SO(d)$ irreps.

e.g. $$\underset{\substack{Osp(d|2)\\ \text{VECTOR}}}{V^a} = \underset{\substack{SO(d)\\ \text{VECTOR}}}{V^\mu} \oplus \underbrace{V^\theta \oplus V^{\bar{\theta}}}_{2\ SO(d)\ \text{SCALARS}}$$

CORRELATORS in PS CFT

$$y_{ij}^2 \equiv (x_i - x_j)^2 - 2(\theta_i - \theta_j)(\bar\theta_i - \bar\theta_j)$$

SUPERSPACE DISTANCE

$$\begin{cases} \langle \mathcal{O}(y_1)\,\mathcal{O}(y_2)\rangle = \dfrac{1}{|y_{12}|^{2\Delta}} \\ \langle \mathcal{O}(y_1)\,\mathcal{O}(y_2)\,\mathcal{O}(y_3)\rangle = \dfrac{\lambda_{123}}{|y_{12}|^{\Delta_1+\Delta_2-\Delta_3}\,|y_{13}|^{\Delta_1+\Delta_3-\Delta_2}\,|y_{23}|^{\Delta_2+\Delta_3-\Delta_1}} \\ \langle \mathcal{O}(y_1)\,\mathcal{O}(y_2)\,\mathcal{O}(y_3)\,\mathcal{O}(y_4)\rangle = \dfrac{1}{|y_{12}|^{2\Delta}\,|y_{34}|^{2\Delta}}\, f(U,V) \end{cases}$$

SUPER CROSS-RATIOS

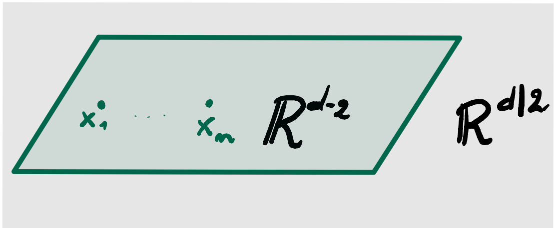
$$\begin{cases} U = \dfrac{y_{12}^2\, y_{34}^2}{y_{13}^2\, y_{24}^2} \\ V = \dfrac{y_{14}^2\, y_{23}^2}{y_{13}^2\, y_{24}^2} \end{cases}$$

same as usual CFT with $x_{ij}^2 \to y_{ij}^2$

PS Reduction/Uplift

DIMENSIONAL REDUCTION

PRESCRIPTION:

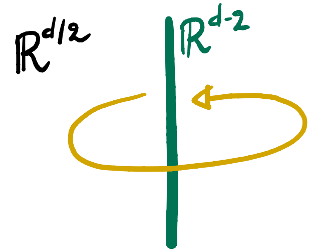


$$\langle \mathcal{O}_1(x_1)\dots\mathcal{O}_n(x_n)\rangle_{\text{P.S. CFT}_d} = \langle \mathcal{O}_1(x_1)\dots\mathcal{O}_n(x_n)\rangle_{\text{CFT}_{d-2}}$$

Decoupling of ∞ many ops

$\boxed{\text{DECOUPLING ARGUMENT}}$

TRIVIAL DEFECT



$$Osp(d+1,1|2) \supset SO(d-1,1) \times Osp(2|2)$$

PS CFT_d — CFT_{d-2} — global sym

DIMENS. REDUCTION: CORRELATOR of $\mathcal{O}_i$: $Osp(2|2)$-SINGLETS

$$\langle \mathcal{O}_1(x_1) \dots \mathcal{O}_m(x_m) \rangle = f(\text{INVARIANTS BUILT out of })$$

g^{ab}_{d-2} — $\parallel$ metric of $\mathbb{R}^{d-2}$

x^a_i — $\Uparrow$ $\mathbb{R}^{d-2}$

$g^{ab}_{2|2}$ — $\perp$ metric of $\mathbb{R}^{2|2}$

$\nexists$ invariant built out of $g_{2|2}$

$$\begin{cases} g^{ab}_{2|2}\, x_a y_b = 0 \\ \mathrm{sTr}\; g_{2|2} = 0 \end{cases}$$

$\longrightarrow$ IN PRACTICE $g_{2|2} \longrightarrow 0$

Consequences of Decoupling

- MAP $\mathbb{O} \longleftrightarrow \mathcal{O}$ e.g. $\mathbb{O} < \begin{cases} \mathcal{O}(x) \in CFT_{d-2} \\ (\partial_\perp^2)^n \mathbb{O}(x) \text{ DECOUPLE} \end{cases}$

- $\exists\ \mathbb{T}^{ab}$ in PS $CFT_d \longrightarrow \exists\ T^{\mu\nu}$ in CFT_{d-2}

- $\mathbb{O}$ OPE EXCHANGE $\longleftrightarrow$ $\mathcal{O}$ OPE EXCHANGE

- $\mathbb{G}^{(d)}_{\Delta,\ell} = g^{(d-2)}_{\Delta,\ell}$

SUPERCONF. BLOCK

CONF. BLOCK

$\boxed{\text{UPLIFT CFT}}$

given $CFT_{d-2} \longrightarrow$ Fully reconstruct PS CFT_d ? HARD

$\exists\ \mathcal{V}$ s.t.
$\mathcal{V} \longrightarrow 0$
NOT REALLY $1-1$
$PS\,CFT_d \supset CFT_{d-2}$

however: $CFT_{d-2} \longrightarrow$ a lot of exact info about PS CFT_d EASY

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e.g. 4PT of SCALARS $\mathcal{O}_i$ $d \geq 4$

$$\langle \mathcal{O}_1 \mathcal{O}_2 \mathcal{O}_3 \mathcal{O}_4 \rangle_{d-2} = \langle \mathcal{O}_1 \mathcal{O}_2 \mathcal{O}_3 \mathcal{O}_4 \rangle_{d/2} \Big|_{\mathbb{R}^{d-2}} \xrightarrow{\text{SYMMETRY}} \langle \mathcal{O}_1 \mathcal{O}_2 \mathcal{O}_3 \mathcal{O}_4 \rangle_{d/2}$$

FULL EXACT RESULT

PRESCRIPTION FOR THE UPLIFT : $\boxed{x_{ij}^2 \longleftrightarrow y_{ij}^2}$

A Structural Check of PS Uplift

$\boxed{\text{STRUCTURAL CHECK of the UPLIFT}}$

if UPLIFT works $\longrightarrow \left\{ \begin{array}{l} \text{all COMPONENTS must be} \\ \text{well defined } CFT_d \text{ observables} \end{array} \right.$

$$\langle UUUU \rangle_{d-2} \longrightarrow \langle \mathcal{U}\mathcal{U}\mathcal{U}\mathcal{U} \rangle_{d|2} = \left\{ \begin{array}{ll} \text{COMPONENTS} & s \\ \langle U_0 U_0 U_0 U_0 \rangle_d & 1 \\ \langle U_\theta U_{\bar\theta} U_0 U_0 \rangle_d & 2 \\ \vdots & \vdots \\ \langle U_{\theta\bar\theta} U_{\theta\bar\theta} U_{\theta\bar\theta} U_{\theta\bar\theta} \rangle_d & 43 \end{array} \right.$$

$f(u,v)$ $\qquad$ $f(U,V)$

$$f_s(u,v) = D_s\, f(u,v)$$

- D_s : COMPUTED $\forall s$ ✓ $\quad \left[\text{e.g. } D_1 = 1,\ D_2 = -(\Delta_1+\Delta_2) + 2u\,\partial_u \right]$
- CHECK f_s : $<$ CROSSING ✓
  CONF. BLOCK DECOMP. in d-dimens. ✓

Conformal Blocks Relations

43 relations between $g^{(d-2)} \longleftrightarrow g^{(d)}$

$$\Longrightarrow \boxed{\mathcal{D}_s\, g^{(d-2)}_{\Delta,\ell} = \sum_{\substack{i,j \\ \leq 5 \text{ TERMS}}} c^{(s)}_{i,j}\; g^{(d)}_{\Delta+i,\,\ell+j}} \qquad s=1,\dots,43$$

e.g. from $\langle \mathcal{O}_\theta \mathcal{O}_\theta \mathcal{O}_{\bar\theta} \mathcal{O}_{\bar\theta} \rangle \Longrightarrow$ $\mathcal{D}\, g^{(d-2)}_{\Delta\ell} = 2(\Delta-1)\ell\; g^{(d)}_{\Delta+1,\,\ell-1}$

[Dolan Osborn '11]

SUSY as a TOOL

SUSY as a TOOL $\rightsquigarrow$ BOOTSTRAPPING GFF

GENER. FREE FIELD (GFF): secretely constrained by PS SUSY !

$$\langle \phi \cdots \phi \rangle \overset{\text{GFF}}{=} \sum \langle \phi\phi \rangle \cdots \langle \phi\phi \rangle \longrightarrow \langle \Phi \cdots \Phi \rangle \overset{\text{PS GFF}}{=} \sum \langle \Phi\Phi \rangle \cdots \langle \Phi\Phi \rangle$$

e.g.

$$\langle \phi\phi\phi\phi \rangle = f(u,v)$$

$$0 = \langle \Phi_{\theta\bar\theta}\, \Phi_0\, \Phi_0\, \Phi_0 \rangle = D_s\, f(u,v)$$

$$\langle \Phi_0\, \Phi_{\theta\bar\theta} \rangle = 0$$

$\Longrightarrow$ $f(u,v)$ satisfies $D_s f = 0$

SOLVE THE OPE COEFF.

$$0 = D_s\, f(u,v)$$

$$= D_s \sum_{\Delta\ell} a_{\Delta\ell}\, g^{(d-2)}_{\Delta\ell}(u,v)$$

USE RELATIONS:

$$D_s\, g^{(d-2)}_{\Delta\ell}(u,v) = \sum_{ij} c^{(s)}_{ij}\, g^{(d)}_{\Delta+i,\,\ell+j}$$

$$= \sum_{\Delta\ell} a_{\Delta\ell} \sum_{ij} c^{(s)}_{ij}\, g^{(d)}_{\Delta+i,\,\ell+j}$$

$$= \sum_{\Delta'\ell'} \underbrace{\Big[\sum_{ij} a\, c\Big]}_{=\,0} g^{(d)}_{\Delta'\ell'} \Longrightarrow$$

RECURRENCE RELATION for $a_{\Delta\ell}$

SOLVE RECURRENCE for $\langle \phi\, \phi^{m_2} \phi^{m_3} \phi^{m_3} \rangle$

$$a^{n_2,n_3,n_3}_{n,\ell} = a^{n_2,n_3}_0 \frac{\left(\frac{\beta_{12}-1}{2}\right)_{\frac{\ell}{2}}\left(\frac{\beta_{12}}{2}\right)_{\frac{\ell}{2}}\left(\frac{\Delta_\phi}{2}\right)_{\frac{\ell}{2}}\left(\frac{\Delta_\phi+1}{2}\right)_{\frac{\ell}{2}}}{\ell!\left(\frac{\beta_{12}-1}{4}\right)_{\frac{\ell}{2}}\left(\frac{\beta_{12}+1}{4}\right)_{\frac{\ell}{2}}} \times$$
$$\times \frac{(-d+\beta_{12}+3)_n\left(-\frac{d}{2}+\Delta_\phi+2\right)_n\left(\frac{\ell+\beta_{12}-1}{2}\right)_n\left(\frac{\ell+\beta_{12}}{2}\right)_n(\ell+\Delta_\phi)_n\left(-\frac{d}{2}+\ell+\beta_{12}+1\right)_n}{2^{4n}n!\left(\frac{d}{2}+\ell-1\right)_n\left(\frac{-d+\beta_{12}+3}{2}\right)_n\left(\ell+\frac{\beta_{12}}{2}-\frac{1}{2}\right)_n\left(\frac{-d+2\ell+2\beta_{12}+2}{4}\right)_n\left(\frac{-d+2\ell+2\beta_{12}+4}{4}\right)_n}$$

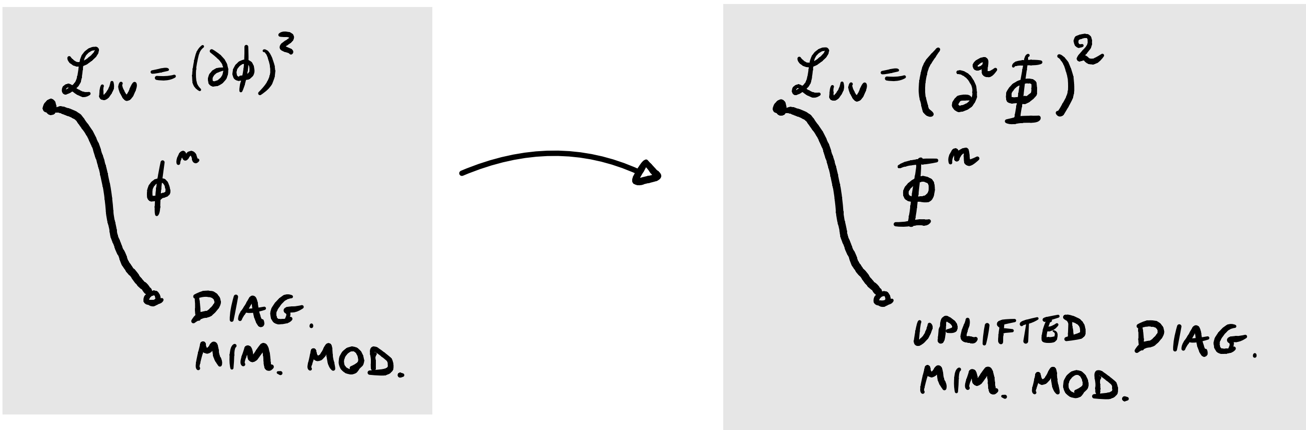
$$\beta_{12} = \Delta_1 + \Delta_2 \qquad a_0^{m_2 m_3} = m_3! \binom{m_2+1}{\frac{m_2+1}{2}} \left(\frac{1-m_2+2m_3}{2}\right)_{\frac{m_2+1}{2}}$$

Uplift Minimal Models

UPLIFT MINIMAL MODELS

- UPLIFT of DIAGONAL MIN. MODELS EXISTS

  ↳ $\mathcal{L}$ argument : all scalar $\mathcal{L}$ can be uplifted



CAN UPLIFT The whole RG FLOW

⟶ ALSO The IR FIXED POINT

EXAMPLE: UPLIFT 2d ISING

ISING : $\sigma, \epsilon, \mathbb{1}$ Virasoro primaries

4PT KNOWN

UPLIFTED 4PT KNOW EXACTLY ✓

$$\langle \epsilon\epsilon\epsilon\epsilon \rangle = f_{\epsilon\epsilon\epsilon\epsilon}(u,v) \longrightarrow D_s\, f_{\epsilon\epsilon\epsilon\epsilon}$$

$$\langle \sigma\sigma\sigma\sigma \rangle = f_{\sigma\sigma\sigma\sigma}(u,v) \longrightarrow D_s\, f_{\sigma\sigma\sigma\sigma}$$

$$\langle \sigma\epsilon\epsilon\sigma \rangle = f_{\sigma\epsilon\epsilon\sigma}(u,v) \longrightarrow D_s\, f_{\sigma\epsilon\epsilon\sigma}$$

$$\langle \sigma\sigma\epsilon\epsilon \rangle = f_{\sigma\sigma\epsilon\epsilon}(u,v) \longrightarrow D_s\, f_{\sigma\sigma\epsilon\epsilon}$$

DECOMPOSE IN CONF. BLOCKS ✓

$[\vec{S}]$	$D_{[\vec{S}]} f_{\epsilon\epsilon\epsilon\epsilon}$
$[\ ]$	$v^{-1}(u^2-uv-u+v^2-v+1)$
$[\mathbf{1}]$	$4v^{-1}(u^2(v+1)-u^3+u(v^2+1)-(v-1)^2(v+1))$
$[\mathbf{2}]$	$4v^{-2}(u^2(v+1)-u^3+u(v^2+1)-(v-1)^2(v+1))$
$[\mathbf{3}]$	$4v^{-2}(u^2(v+1)-u^3+u(v^2+1)-(v-1)^2(v+1))$
$[\mathbf{4}]$	$4v^{-1}(u^2(v+1)-u^3+u(v^2+1)-(v-1)^2(v+1))$
$[1\bar{2}]$	$2v^{-1}(u^2-v^2+v-1)$
$[3\bar{4}]$	$2v^{-1}(u^2-v^2+v-1)$
$[1\bar{2}3\bar{4}]$	$-4v^{-2}(u-v)((u-1)u+(v-1)v+1)$
$[1\bar{2}4\bar{3}]$	$-4v^{-1}(-1+u)(1+u^2-(1+u)v+v^2)$
$[\mathbf{13}\bar{4}]$	$-8v^{-1}(-u^2(v+1)+u^3+u(v^2+1)-(v-1)^2(v+1))$
$[\mathbf{23}\bar{4}]$	$-8v^{-2}(-u^2(v+1)+u^3+u(v^2+1)-(v-1)^2(v+1))$
$[\mathbf{31}\bar{2}]$	$-8v^{-2}(-u^2(v+1)+u^3+u(v^2+1)-(v-1)^2(v+1))$
$[\mathbf{41}\bar{2}]$	$-8v^{-1}(-u^2(v+1)+u^3+u(v^2+1)-(v-1)^2(v+1))$
$[\mathbf{12}]$	$16v^{-2}(u^2(v^2+1)-u^3(v+1)+u^4+u(-3v^3+v^2+v-3)+2(v-1)^2(v^2+1))$
$[\mathbf{13}]$	$16v^{-2}(u^2(4v^2+v+1)-u^3(4v+3)+2u^4+u(-4v^3+v^2-1)+(v-1)^2(2v^2+v+1))$
$[\mathbf{14}]$	$16v^{-1}((u^2+1)v^2+(-3u^3+u^2+u-3)v+2(u-1)^2(u^2+1)-(u+1)v^3+v^4)$
$[\mathbf{23}]$	$16v^{-3}((u^2+1)v^2+(-3u^3+u^2+u-3)v+2(u-1)^2(u^2+1)-(u+1)v^3+v^4)$
$[\mathbf{24}]$	$16v^{-2}(u^2(4v^2+v+1)-u^3(4v+3)+2u^4+u(-4v^3+v^2-1)+(v-1)^2(2v^2+v+1))$
$[\mathbf{34}]$	$16v^{-2}(u^2(v^2+1)-u^3(v+1)+u^4+u(-3v^3+v^2+v-3)+2(v-1)^2(v^2+1))$
$[\mathbf{123}\bar{4}]$	$-32v^{-2}(u^2(v^2+1)+u^3(v+1)-u^4+u(-3v^3+v^2+v-3)+2(v-1)^2(v^2+1))$
$[1\bar{2}\mathbf{34}]$	$-32v^{-2}(u^2(v^2+1)+u^3(v+1)-u^4+u(-3v^3+v^2+v-3)+2(v-1)^2(v^2+1))$
$[\mathbf{123}]$	$-256v^{-3}(u^2-u(v+1)+(v-1)v+1)(-u^2(v+1)+u^3-u(v^2+1)+(v-1)^2(v+1))$
$[\mathbf{124}]$	$-256v^{-2}(u^2-u(v+1)+(v-1)v+1)(-u^2(v+1)+u^3-u(v^2+1)+(v-1)^2(v+1))$
$[\mathbf{134}]$	$-256v^{-2}(u^2-u(v+1)+(v-1)v+1)(-u^2(v+1)+u^3-u(v^2+1)+(v-1)^2(v+1))$
$[\mathbf{234}]$	$-256v^{-3}(u^2-u(v+1)+(v-1)v+1)(-u^2(v+1)+u^3-u(v^2+1)+(v-1)^2(v+1))$
$\vdots$	$\vdots$

43 CASES

(d=4)

$$= \sum_{\Delta\ell} a_{\Delta\ell}\, g_{\Delta\ell}(u,v)$$

(Δ,ℓ)	(0,0)	(2,0)	(2,2)	(4,0)	(4,2)	(4,4)	(6,0)
$a_{\Delta\ell}$	1	-1	4	1	$\frac{-2}{3}$	$\frac{8}{5}$	$\frac{-1}{6}$
(Δ,ℓ)	(6,2)	(6,4)	(6,6)	(8,0)	(8,2)	(8,4)	(8,6)
$a_{\Delta\ell}$	$\frac{2}{5}$	$\frac{-8}{35}$	$\frac{32}{63}$	$\frac{1}{60}$	$\frac{-2}{35}$	$\frac{8}{63}$	$\frac{-16}{231}$
(Δ,ℓ)	(8,8)	(10,0)	(10,2)	(10,4)	(10,6)	(10,8)	(10,10)
$a_{\Delta\ell}$	$\frac{64}{429}$	$\frac{-1}{700}$	$\frac{1}{189}$	$\frac{-4}{231}$	$\frac{16}{429}$	$\frac{-128}{6435}$	$\frac{512}{12155}$

...

FEATURES:

- $a_{\Delta\ell}$ CAN BE NEGATIVE
- Δ,ℓ BELOW UNITARITY BOUND $\Delta \geq \ell + d - 2$, $\Delta \geq \frac{d}{2} - 1$
- ∞-MANY CONSERVED HIGHER-SPIN CURRENTS $\Delta = \ell + 2$

SYMMETRIES

2d ISING GLOBAL CURRENTS

$L_{-k}^{m_k} \cdots L_{-2}^{m_2} \mathbb{1}$ $\longrightarrow$ UPLIFTED GLOBAL CURRENTS $J^{a_1 \cdots a_\ell}_{\{m_2, \ldots, m_k\}}$

grows as $e^{\sqrt{\ell}}$

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each $J^{a_1 \cdots a_\ell}_{\{m_2, \ldots, m_k\}} \longrightarrow$ TOPOLOGICAL OPERATORS $\longrightarrow$ CHARGES

$\Longrightarrow$ EXTENSION of VIRASORO $\longleftarrow$ To do

e.g. $L_{-1}, \bar{L}_{-1}$ v.s. $P^{a=1,..,4,\theta,\bar{\theta}}$

Summary

Explain/Check PS Reduction/Uplift

PS Uplift

- Relations between $g^{(d-2)}_{\Delta \ell} \longleftrightarrow g^{(d)}_{\Delta \ell}$
- Tool to Bootstrap GFF
- Definition of Solvable $\mathrm{CFT}_{d>2}$

OUTLOOK

- EXTEND TO <u>SPINNING CORRELATORS</u>

  SUSY as a TOOL $\rightarrow$ CFT_{d-2} SPINNING BOOTSTRAP $\langle TTTT \rangle$ $\overset{?}{\longleftrightarrow}$ PS CFT_d SCALAR BOOTSTRAP $\langle \mathcal{O}\mathcal{O}\mathcal{O}\mathcal{O} \rangle$

- FULLY <u>SOLVE UPLIFTED MIN. MODELS</u>

- <u>~~SUSY~~ DEFORMATIONS</u> of UPLIFTED CFTs

- <u>PROVE/DISPROVE CONJECTURE</u>:

  GIVEN CFT_{d-2}, $\exists$ UNIQUE PS UPLIFT

Thanks