CFT Genome Project: 3d QED Bootstrap

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Based on: Z. Li, “Solving QED_3 with Conformal Bootstrap,” arXiv:1812.09281 [hep-th].

CFT genome project:

Classification of CFTs in D>2 based on small number of relevant operators.

Some particularly important theories:

- **3D Ising/O(N) vector model**;

  (F. Kos, S. EI-Showk, M. Paulos, D. Poland, S. Rychkov, D. Simmons-Duffin, A. Vichi, etc.)

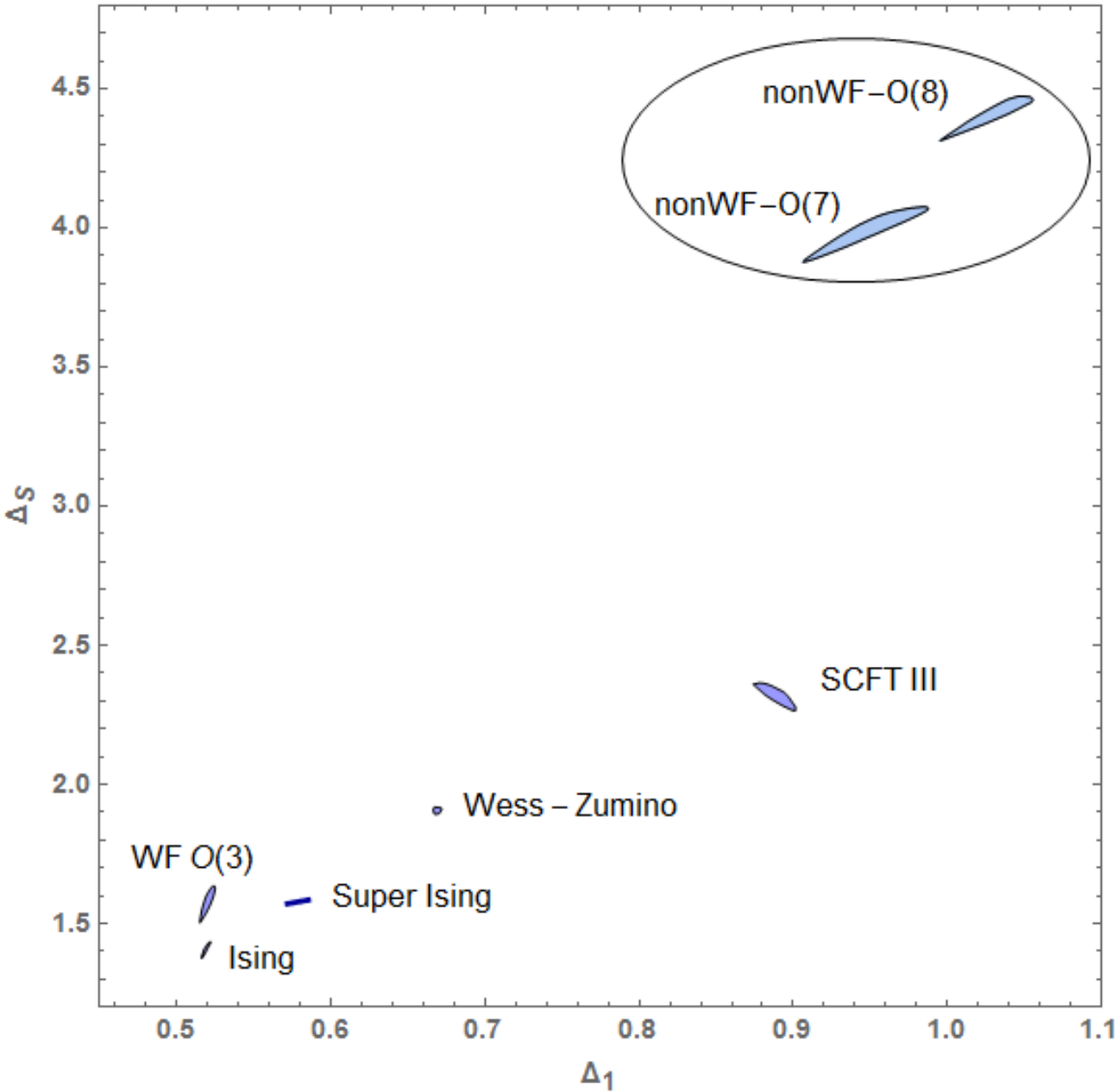
- **3D QED**: IR f-p above critical flavor number;

  (S. Chester, L. Iliesiu, Z.L, Y. Nakayama, T. Ohtsuki, S. Pufu)

- **4D QCD**: Banks-Zaks f-p in the conformal window

  (H. Iha, H. Makino, Y. Nakayama, H. Suzuki.)

A small part of 3d CFT Landscape:



3d QED:

- Lagrangian for 3d QED:

$$\mathcal{L} = -\frac{1}{4e^2} F^{\mu\nu} F_{\mu\nu} + i \sum_{a=1}^{2N} \bar{\Psi}_a \not{D} \Psi^a + \mathcal{L}_{\text{mass}} + \mathcal{L}_{\text{4-fermion}}$$

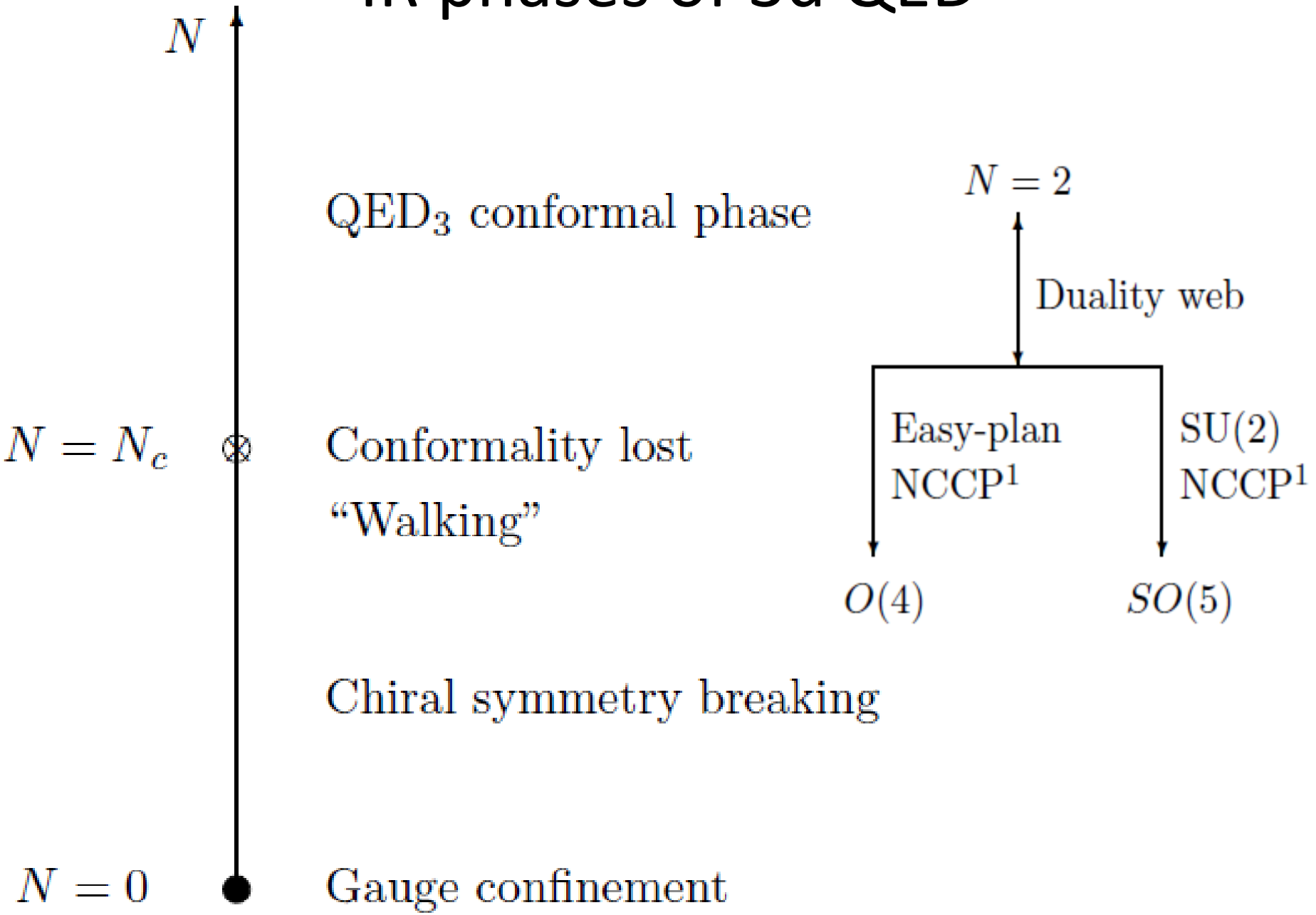
- Chiral symmetry: **SU(2N)** (no mass and 4-fermion terms)
- There are two possible mass terms:

$$\sum_{a=1}^{N} (\bar{\Psi}_a \Psi^a - \bar{\Psi}_{a+N} \Psi^{a+N}) \qquad SU(N) \times SU(N) \times U(1) \& P \& T$$

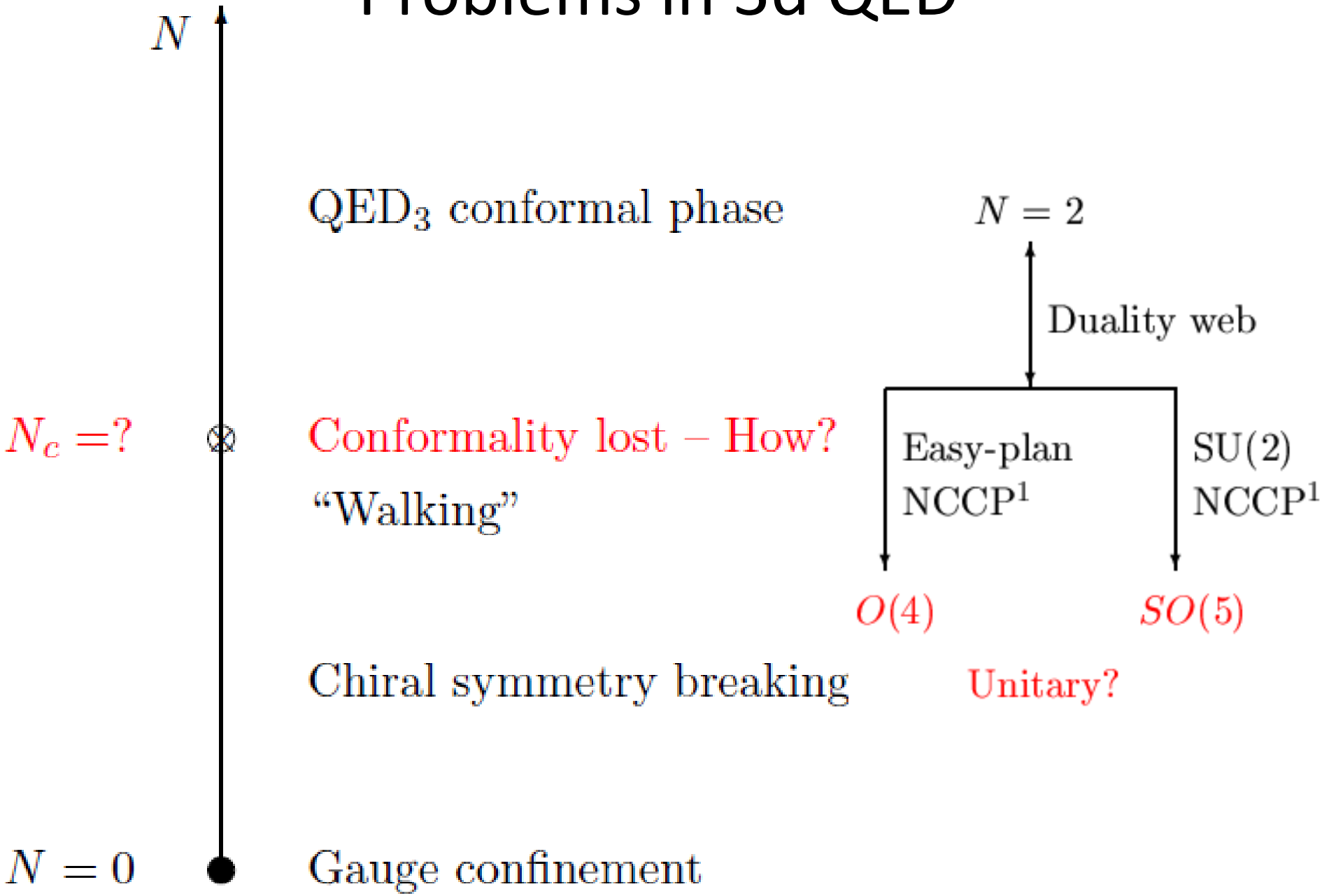
$$\sum_{a=1}^{2N} \bar{\Psi}_a \Psi^a \qquad SU(2N), \not{P}, \not{T}$$

- 4-fermion terms are **irrelevant** in UV, but may become **relevant** in IR for small N.
- UV phase: **asymptotically free** (gauge coupling *e* has positive mass unit).

IR phases of 3d QED



Problems in 3d QED



Bootstrap study of 3d QED

- U(1) gauge invariant fermion bilinear:

$$\mathcal{O}^A = \bar{\Psi} T^A \Psi,$$

adjoint representation of SU(2N).

- Crossing equation for SU(N)-adjoint bootstrap:

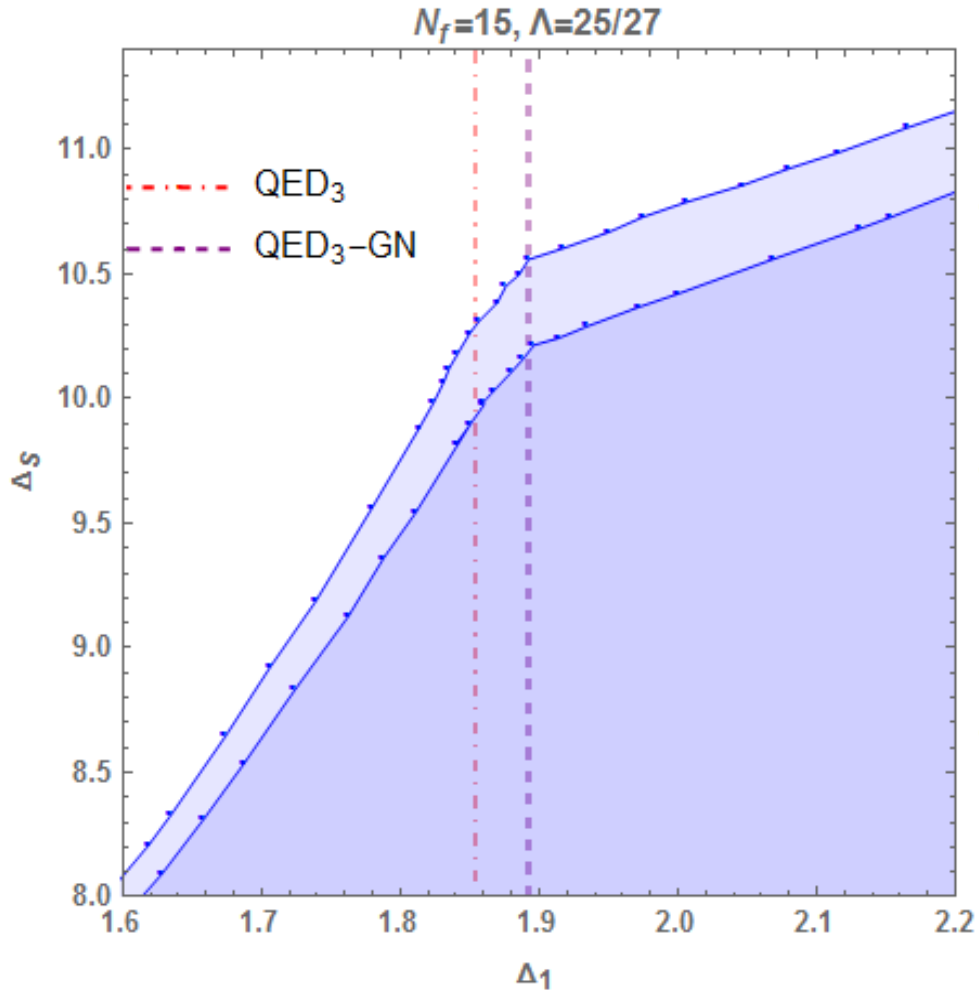
$$\langle \overbrace{\mathcal{O}^A(x_1)\mathcal{O}^B(x_2)}\underbrace{\mathcal{O}^C(x_3)\mathcal{O}^D(x_4)}\rangle = \langle \overbrace{\mathcal{O}^A(x_1)\underbrace{\mathcal{O}^B(x_2)\mathcal{O}^C(x_3)}\mathcal{O}^D(x_4)}\rangle$$

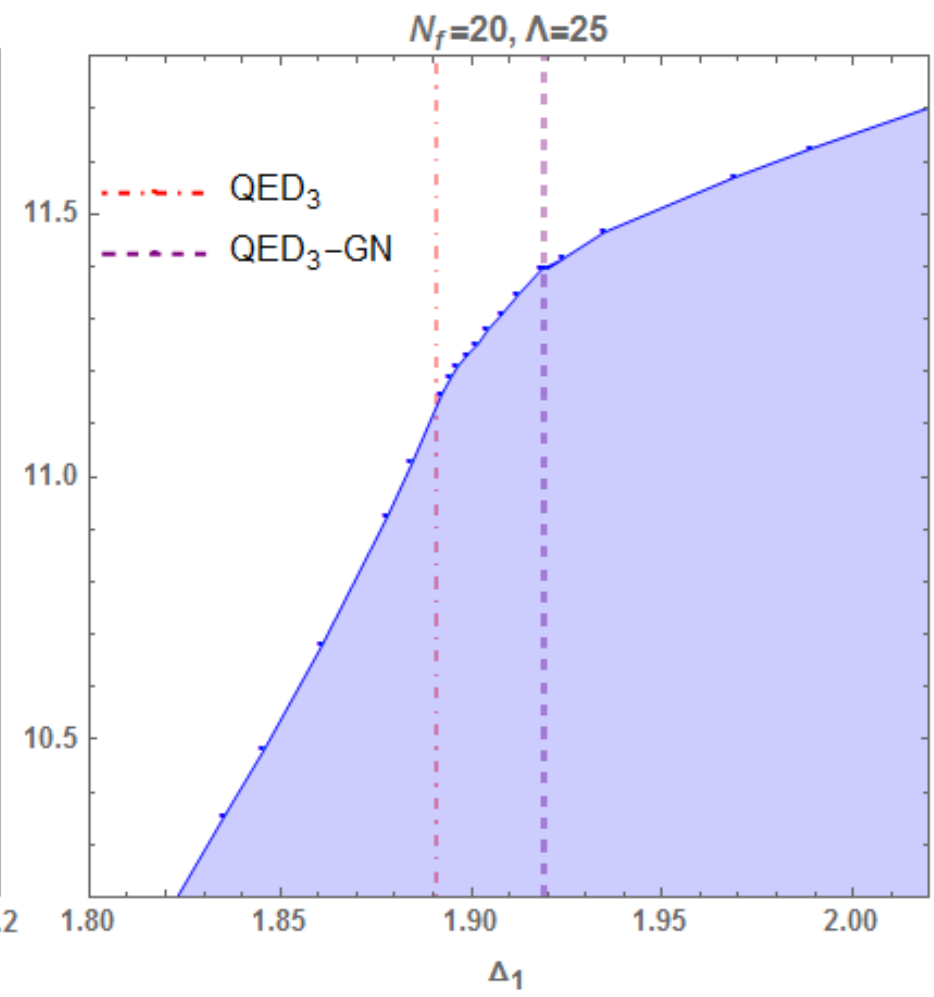
- Unitarity:

$$\lambda^2_{12\mathcal{O}} \geqslant 0, \quad \text{or} \qquad \Delta = 0 \text{ (unit operator), or}$$

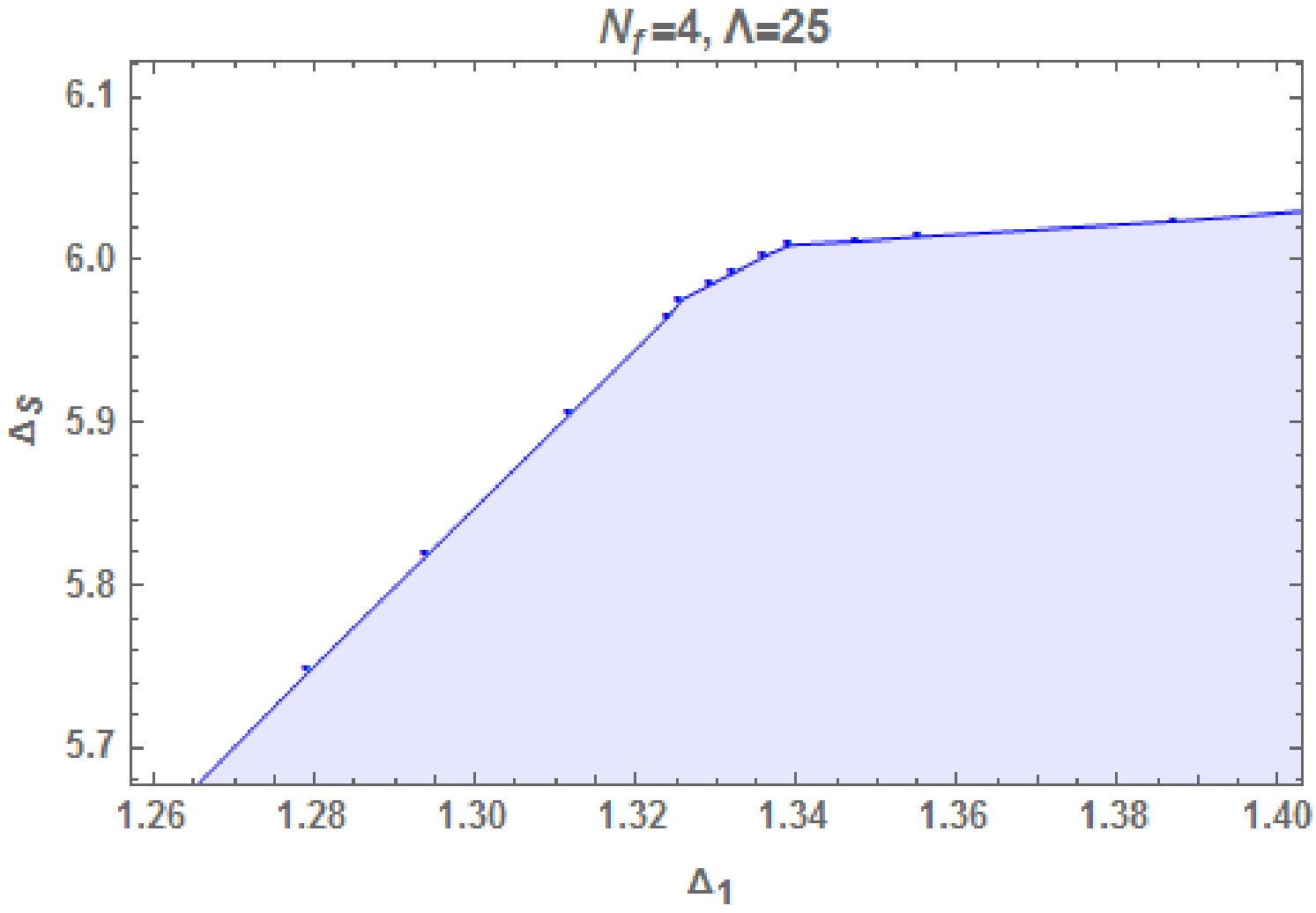
$$\lambda_{12\mathcal{O}}\lambda^\dagger_{12\mathcal{O}} \geqslant 0, \qquad \Delta \geq \begin{cases} \frac{d-2}{2} & \ell = 0, \\ \ell + d - 2 & \ell > 0. \end{cases}$$

Large N: comparisons between bootstrap results and 1/N expansion

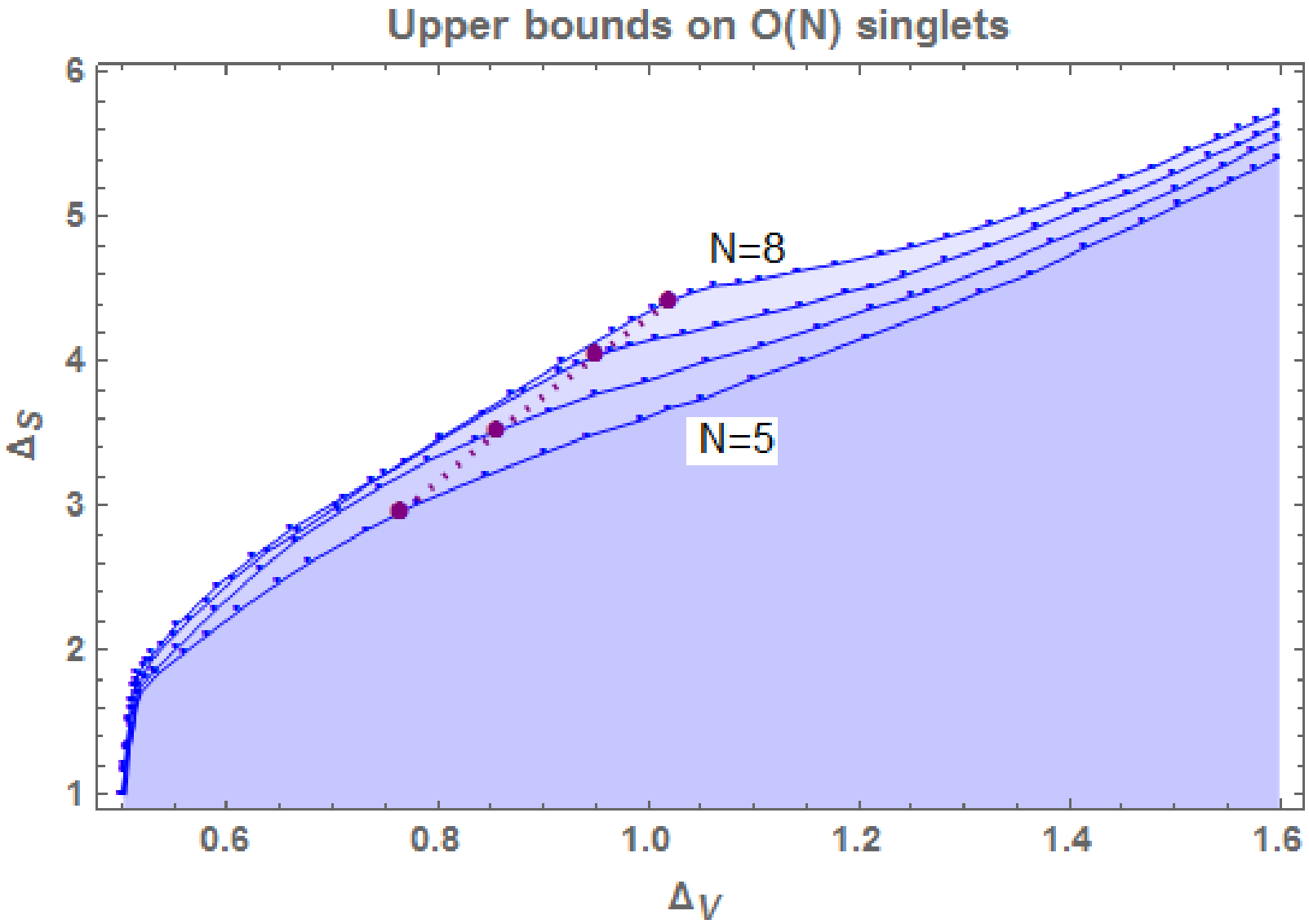




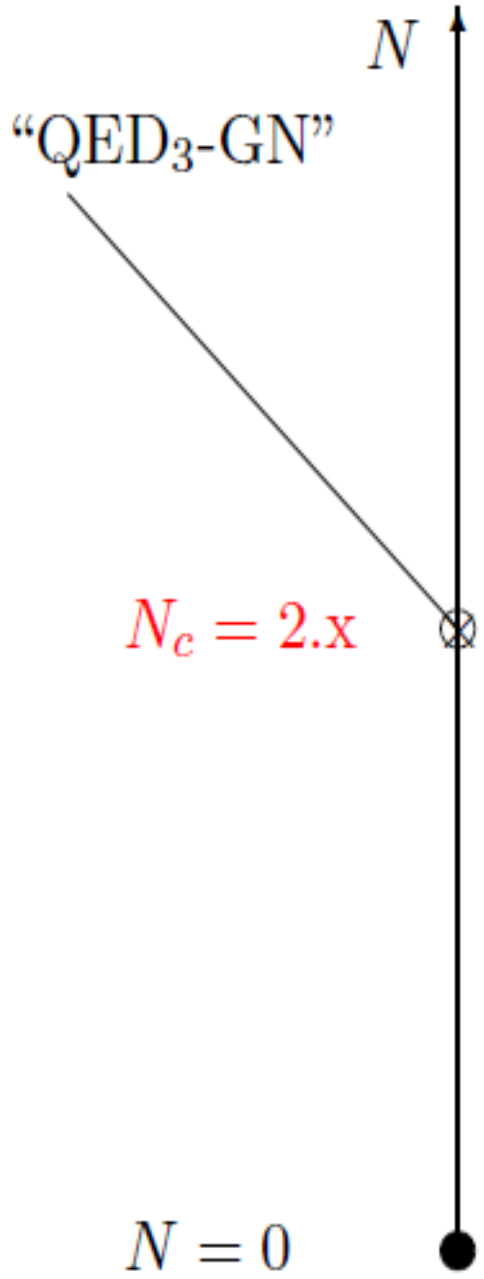
Small flavor number N=4 (critical N=2):



IR fixed point with O(4)/SO(5) symmetry enhancement:



Conclusions:



QED_3 conformal phase

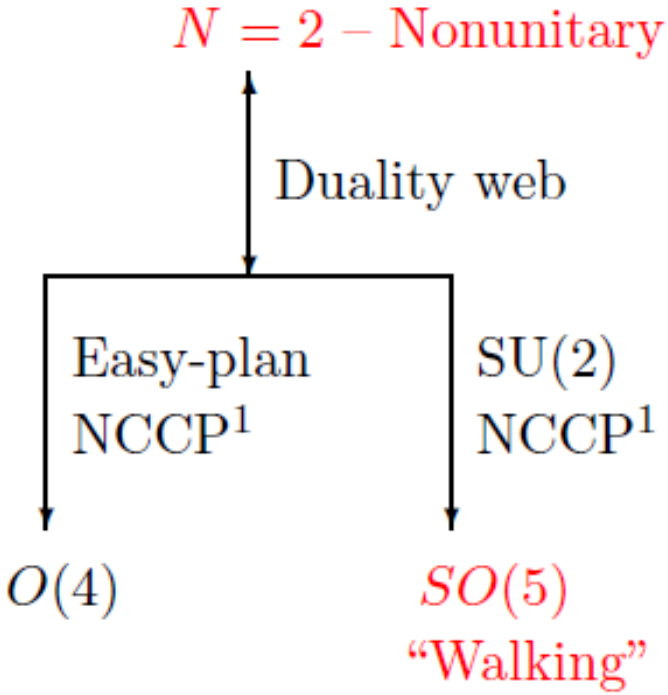
Conformality lost

Merger & annihilation

$\Psi^4 \rightarrow$ relevant

Chiral symmetry breaking

Gauge confinement



Future studies

- **3d QED mixed correlators bootstrap**
- **Supersymmetric generalization**
- **4d QCD:**

  Banks-Zaks fixed points

  Conformal window Nf/Nc >= ?

  Conformality lost QCD^*?