Mergers in Gauge - Yukawa Theories @ 432

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Gauge-Yukawa Model

$$\begin{aligned}\mathcal{L}_{GY} =& -\frac{1}{2}\,\mathrm{Tr}(F^{\mu\nu}F_{\mu\nu}) \\ &+ \bar{\Psi} i \not{D} \Psi + y(\bar{\Psi}_L H \Psi_R + \Psi_L H^\dagger \bar{\Psi}_R) \\ &+ \mathrm{Tr}(\partial_\mu H^\dagger \partial^\mu H) - u\,\mathrm{Tr}((H^\dagger H)^2) - v(\mathrm{Tr}(H^\dagger H))^2\end{aligned} \tag{1}$$

Veneziano Limit

$$\epsilon = \frac{N_f}{N_c} - \frac{11}{2} \tag{2}$$

- $\beta_g^{(1)} = \frac{4\epsilon}{3}\alpha_g^2$ (under the re-scaling of couplings)
- Veneziano limit $\longrightarrow \epsilon \in (\infty, -\frac{11}{2})$
- $\epsilon < 0 \Longrightarrow$ Asymptotically free, Banks-Zaks[1]
- $\epsilon > 0 \Longrightarrow$ **UV interacting fixed point**

[1] Caswell '74, T. Banks, A. Zaks '82

UV Interacting Fixed Point @ 210

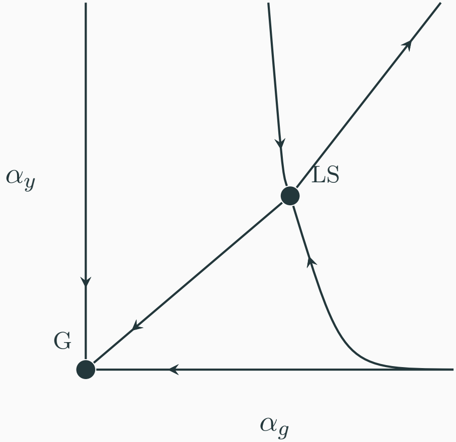
$$\begin{aligned}\beta_g &= \frac{4\epsilon}{3}\alpha_g^2 + \left(\frac{26\epsilon}{3} + 25\right)\alpha_g^3 - \frac{1}{2}\left(11 + 2\epsilon\right)^2 \alpha_g^2\alpha_y \\ \beta_y &= \left(13 + 2\epsilon\right)\alpha_y^2 - 6\alpha_g\alpha_y\end{aligned} \tag{3}$$

- *Litim-Sannino* fixed point[2]

$$\begin{aligned}\alpha_g^* &= 0.456\epsilon + 0.438\epsilon^2 + 0.4177\epsilon^3 + \mathcal{O}(\epsilon^4) \\ \alpha_y^* &= 0.211\epsilon + 1.700\epsilon^2 + 0.167\epsilon^3 + \mathcal{O}(\epsilon^4)\end{aligned} \tag{4}$$

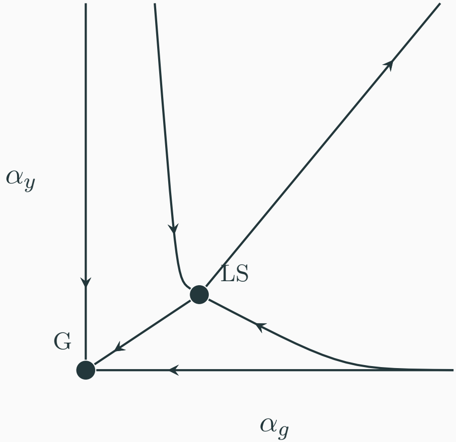
[2] ArXiv:1406.2337 - Litim, Sannino '14

Litim - Sannino Fixed Point



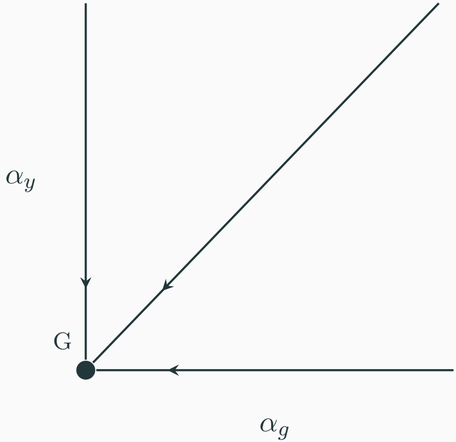
$$0 < \epsilon \ll 1$$

Litim - Sannino Fixed Point



$\epsilon \to 0$

Gaussian Fixed Point

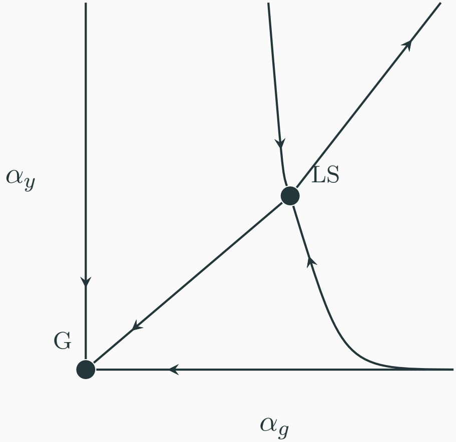


$\epsilon = 0$

What happens when we dial ϵ up in `210`?

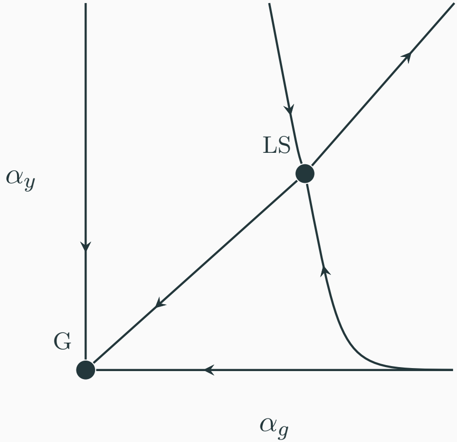
- LS becomes strongly coupled
- What happens at order `211`?

Litim - Sannino Fixed Point @ 211

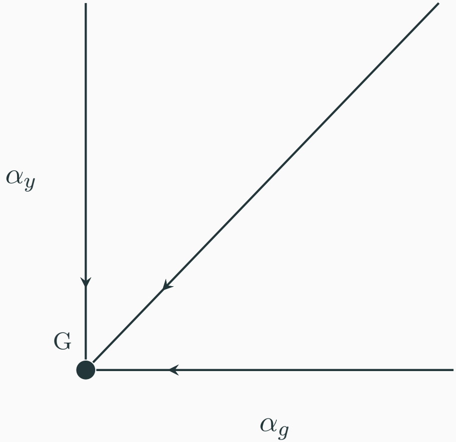


$$0 < \epsilon \ll 1$$

Increasing ϵ @ 211



Disappearing Fixed Point @ 211



Fixed Point @ 322

$$
\begin{aligned}
\alpha_g^* &= 0.456\epsilon + 0.781\epsilon^2 + \mathcal{O}(\epsilon^3) \\
\alpha_y^* &= 0.211\epsilon + 0.508\epsilon^2 + \mathcal{O}(\epsilon^3) \\
\alpha_u^* &= 0.200\epsilon + 0.440\epsilon^2 + \mathcal{O}(\epsilon^3) \\
\alpha_v^* &= -0.137\epsilon - 0.856\epsilon^2 + \mathcal{O}(\epsilon^3)
\end{aligned}
\tag{5}
$$

Scaling Exponents @ 322

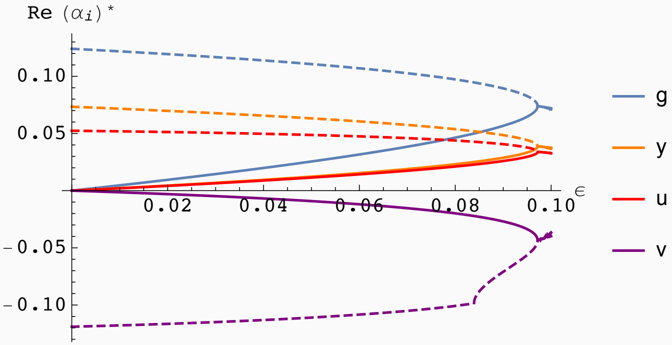
$$
\begin{aligned}
\theta_1 &= -0.608\epsilon^2 + 0.707\epsilon^3 + \mathcal{O}(\epsilon^4) \\
\theta_2 &= 2.737\epsilon + 6.676\epsilon^2 + \mathcal{O}(\epsilon^3) \\
\theta_3 &= 2.941\epsilon - 0.755\epsilon^2 + \mathcal{O}(\epsilon^3) \\
\theta_4 &= 4.039\epsilon + 9.107\epsilon^2 + \mathcal{O}(\epsilon^3)
\end{aligned} \tag{6}
$$

Merger in gauge-Yukawa model @ 322

There exists another branch of fixed point solutions to the beta functions but this is outside strict perturbative control.

$$\alpha^*_{IR} = K + B\epsilon^2 + \mathcal{O}(\epsilon^3) \tag{7}$$

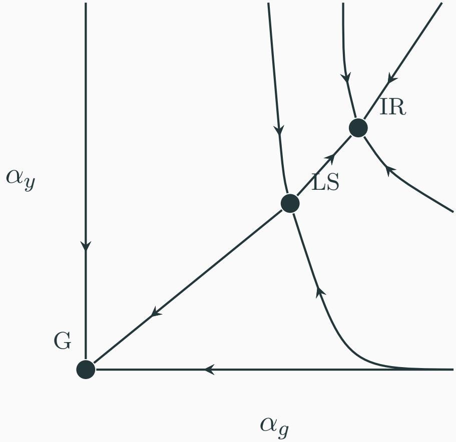
Merger in 322 - Fixed Points vs ϵ



$$\epsilon_{merge} \simeq 0.097^3$$

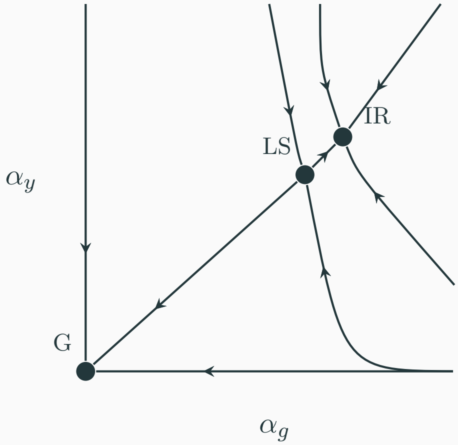
[3] ArXiv:2107.13020 - Bond, Litim, Vazquez '21

Merger in gauge-Yukawa model @ 322



$$0 < \epsilon \ll 1$$

Merger in gauge-Yukawa model @ 322



$$\epsilon \longrightarrow \epsilon_{merge}$$

More Loops

Next loop order for (consistent) fixed point solutions is 433

Fixed Point @ 432

$$
\begin{aligned}
\alpha_g^* &= 0.456\epsilon + 0.781\epsilon^2 + 6.610\epsilon^3 + \mathcal{O}(\epsilon^4) \\
\alpha_y^* &= 0.211\epsilon + 0.508\epsilon^2 + 3.322\epsilon^3 + \mathcal{O}(\epsilon^4) \\
\alpha_u^* &= 0.200\epsilon + 0.440\epsilon^2 + \mathcal{O}(\epsilon^3) \\
\alpha_v^* &= -0.137\epsilon - 0.632\epsilon^2 + \mathcal{O}(\epsilon^3)
\end{aligned}
\tag{8}
$$

Scaling Exponents @ 432

$$
\begin{aligned}
\theta_1 &= -0.608\epsilon^2 + 0.707\epsilon^3 + 6.947\epsilon^4 + \mathcal{O}(\epsilon^5) \\
\theta_2 &= 2.737\epsilon + 6.676\epsilon^2 + 22.120\epsilon^3 + \mathcal{O}(\epsilon^4) \\
\theta_3 &= 2.941\epsilon + 1.041\epsilon^2 + \mathcal{O}(\epsilon^3) \\
\theta_4 &= 4.039\epsilon + 9.107\epsilon^2 + \mathcal{O}(\epsilon^3)
\end{aligned} \tag{9}
$$

Mergers in 432

There seem to be indications of a merger around $\epsilon \simeq 0.136$

To Consider @ 433

- Does the fixed point merger from 322 persist at 433?
- Is the merger perturbatively reliable?
- Computational load at higher loop orders

Summary

- The gauge-Yukawa model $\mathcal{L}_{GY}$ exhibits a UV interacting (*Litim-Sannino*) fixed point
- Mergers are one way that fixed points can disappear
- Bounds on ϵ[4]: Vaccuum stability, weak coupling, negative coupling

[4] ArXiv:1710.07615 - Bond, Litim, Vazquez, Steudtner '17

Summary

- At `322`, we see such a merger between the UV interacting fixed point and a (strongly coupled) IR fixed point
- Work in progress to see if this persists at `433`

Conformal Windows Beyond Asymptotic Freedom

- ArXiv:1406.2337 - Litim, Sannino ‘14
- ArXiv:1710.07615 - Bond, Litim, Vazquez, Steudtner ‘17
- ArXiv:2107.13020 - Bond, Litim, Vazquez ‘21

Thank you for listening.