

# Dark matter and Unification

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## Motivation and model

- ▶ Existence of dark matter  $\rightarrow$  new particles
- ▶ We do not see new particles yet  $\rightarrow$  minimal extension

Adding vector-like fermion dublet(s)  $\left(\Psi_D = \begin{pmatrix} \Psi^0 \\ \Psi^+ \end{pmatrix}\right)$  and singlet fermion(s) ( $\Psi_S$ ) to the Standard model.

- ▶ *vector-like fermion = not chiral*

$$\mathcal{L}_{DS} = -\lambda\Psi_D h\Psi_S - \lambda'\bar{\Psi}_D \tilde{h}\Psi_S - M_D\bar{\Psi}_D\Psi_D - \frac{1}{2}M_S\Psi_S\Psi_S + h.c.$$

# Unification

Can this extension help in gauge unification?

- ▶ adding more doublets?  $\rightarrow n_{eff} = 1.5$  from mass of 1 TeV  $\rightarrow$  can we have theory like that?
- ▶ mixing in the neutral section?

$$M = \begin{pmatrix} M_S & \frac{\lambda v}{\sqrt{2}} & \frac{\lambda' v}{\sqrt{2}} \\ \frac{\lambda v}{\sqrt{2}} & 0 & M_D \\ \frac{\lambda' v}{\sqrt{2}} & M_D & 0 \end{pmatrix} \rightarrow \begin{pmatrix} \Psi_1 \\ \Psi_2 \\ \Psi_3 \end{pmatrix} = U \begin{pmatrix} \Psi_S \\ \Psi^0 \\ \bar{\Psi}^0 \end{pmatrix}$$

## More vector-like fermions

- ▶ Adding two doublets with mass  $M_D = 3.95 \times 10^4 \text{ GeV}$ .

