Axiverse Baryogenesis[†]

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Based on : 2512.20696, 2606.SOON
With : David Cyncynates, Stefania Gori

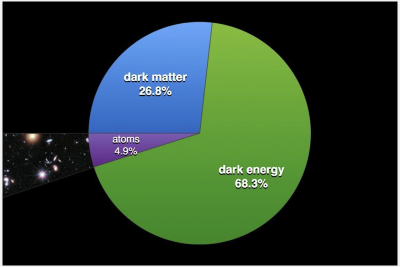
Talk Presented @ PHENO 2026

[†] With Color Commentary

May 11, 2026

The Matter Coincidence Problem

- A curious pattern



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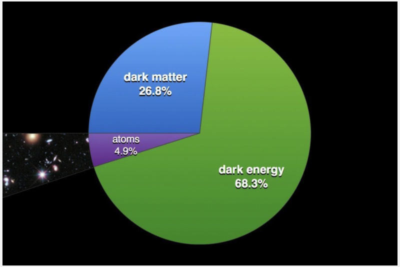

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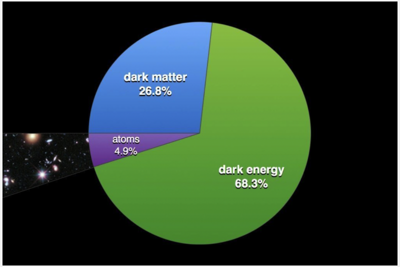

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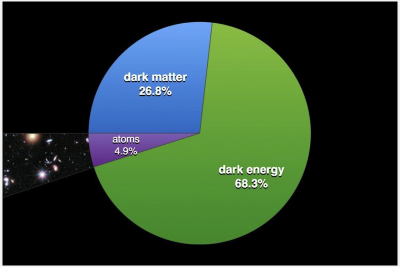

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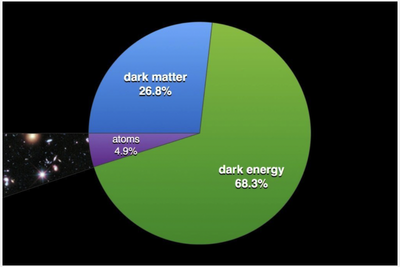

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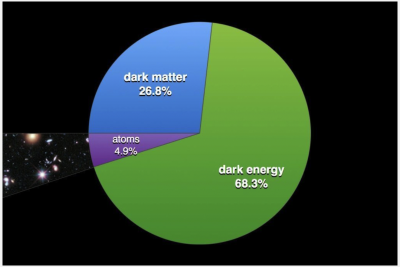

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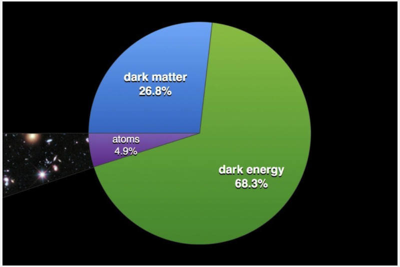

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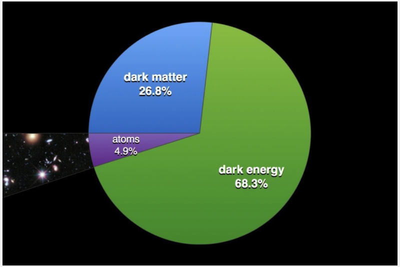

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- Strongest hint for DM-SM interaction. Solutions can drive searches.
- Axion is a motivated DM candidate. An axion cogenesis model?††

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†† Proposal: An axion's main competitor should be called a *Nelson*.

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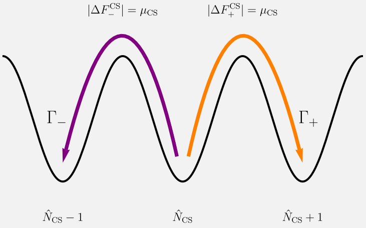

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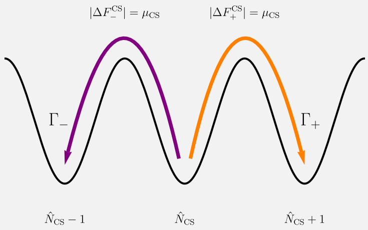

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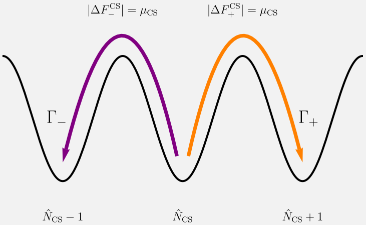

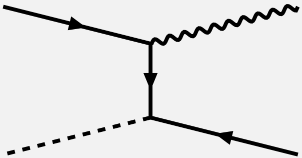

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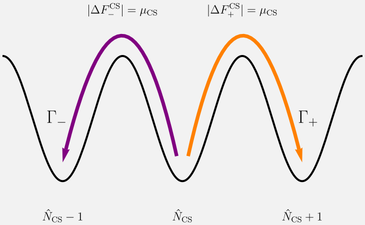

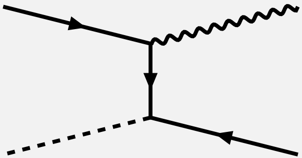

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Generating this velocity requires PQ violation: quality problem.

Asymmetries Backreaction on Axion: Friction

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- $\dot{\theta}(T_{\rm EW}) \sim 5$ keV: sustained to low T and overproduces axion DM.
- A new confining sector can have the suitable friction![††]

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[††] Conjecture: There is no problem in life that can't be solved by a new confining force.

Axiogenesis in the Axiverse

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- Solves the strong CP problem + a cogenesis model.

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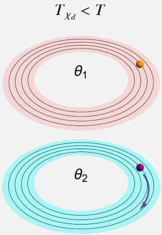

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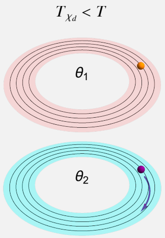

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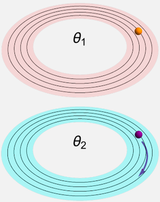

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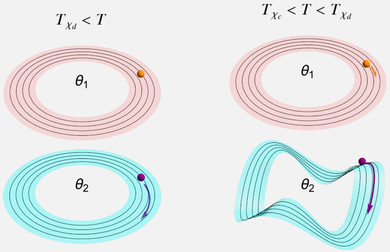

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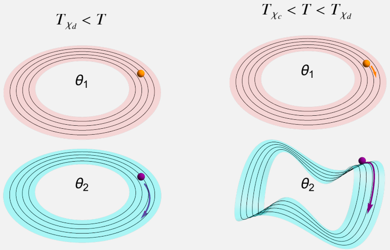

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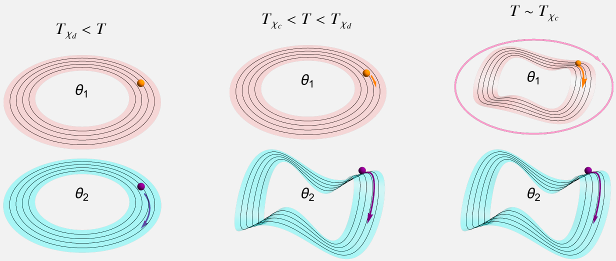

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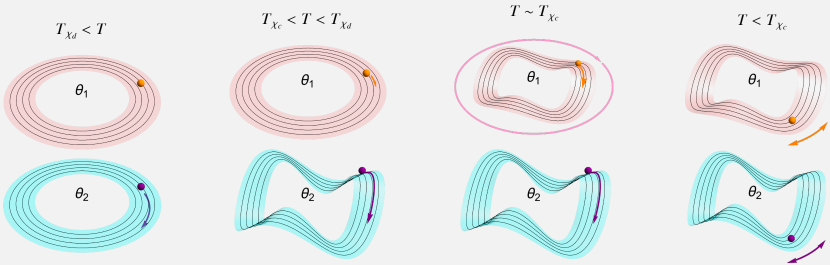

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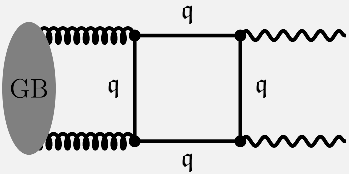

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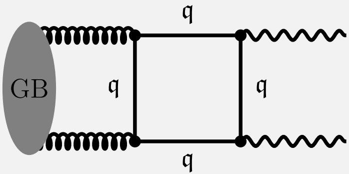

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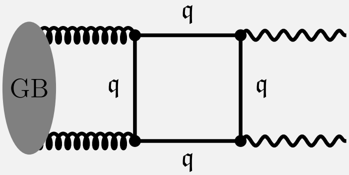

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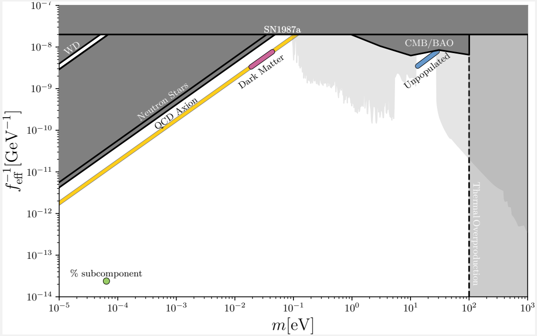

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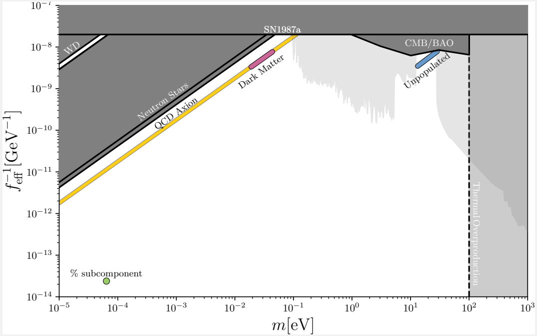

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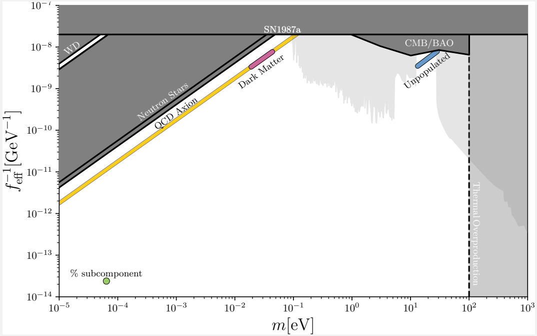

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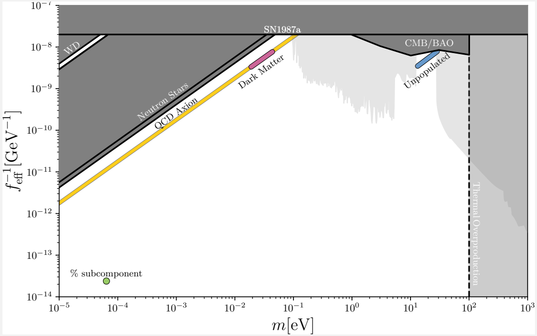

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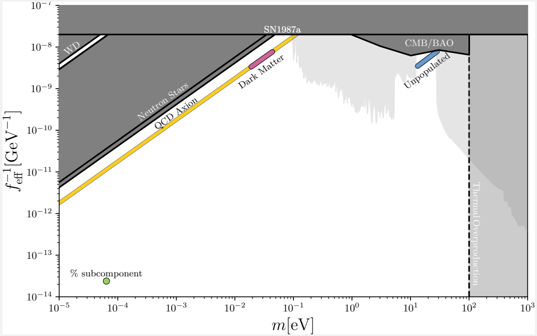

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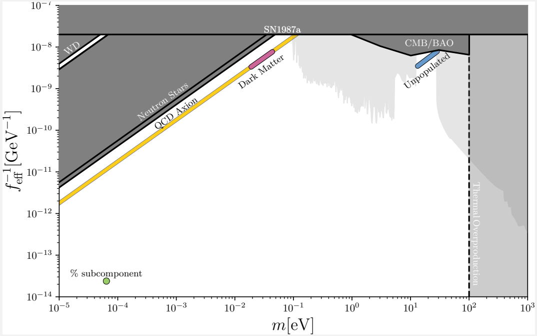
- Blue region: viable space roughly fixed (thanks to friction and glueball bounds).



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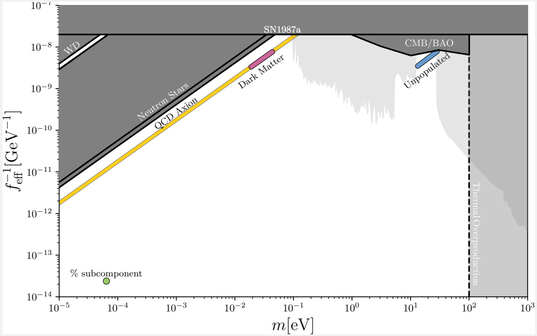
Parameter Space

- Part of the viable parameter space.†
    - All fs equal, Λ_d GeV, UV potential parameter fixed.
- QCD axion makes up bulk of DM today — can be anywhere on the QCD line.
- Other two constitute a sub-component of DM today.
- Blue region: viable space roughly fixed (thanks to friction and glueball bounds).
- We have signals at colliders too.



† Turns out simulating three non-linear coupled oscillators is difficult!

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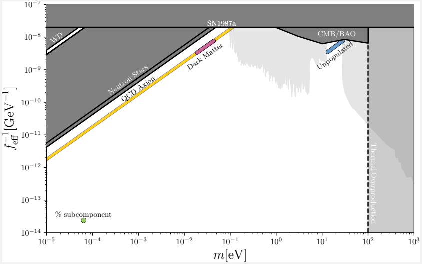

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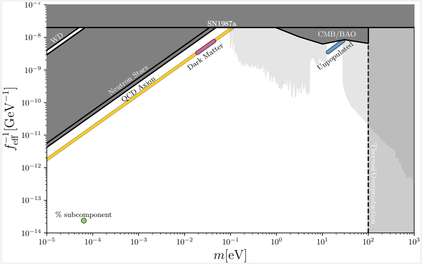

Defines new correlated targets for experiments (in collider and cosmology).

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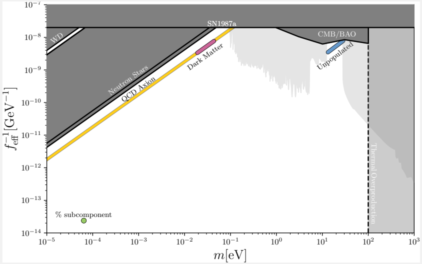

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THANK YOU!

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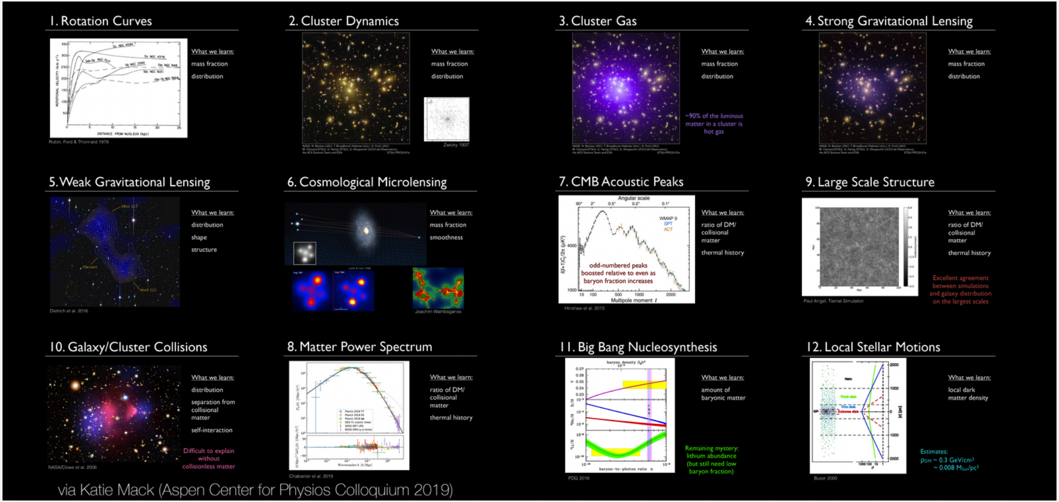
Back up

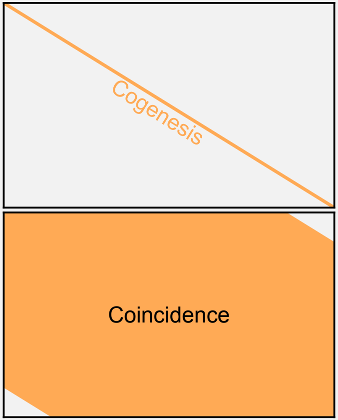
- Evidence For DM
- Coincidence vs Cogenesis
- $\dot{\theta}$ as CS Chemical Potential
- Fermion Contribution to Free Energy
- Finite T Effects in Chirality flipping
- Friction and Kinetic Misalignment
- Susceptibility
- Quarks and Glueballs
- Other Scenarios
- UV Completion

Evidence for DM



Coincidence vs. Cogenesis

- Coincidence models $\neq$ Cogenesis models!
  - Is the ratio of abundances *generically* $\mathcal{O}(1)$?
- We put forward a cogenesis mechanism - future step: coincidence.
- Do any of motivated DM models fit in a cogenesis setup?
  - Let's explore this in QCD axion DM models.

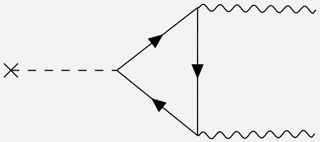


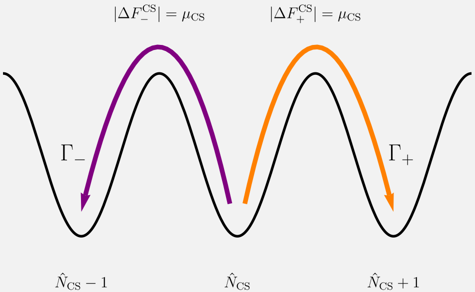
CS Chemical Potential

$$\begin{aligned}\mathcal{S} = \int d^4x\, \mathcal{L} \supset \int d^4x\, \frac{\alpha}{8\pi}\, \zeta\, W^a_{\mu\nu} \tilde{W}^{\mu\nu\ a} &= \int d^4x\, \zeta\, \partial_\mu j^\mu_{\text{CS}} \\ &= \int d^4x\, \zeta\, \partial_t j^0_{\text{CS}} \\ &= -\int d^4x\, \partial_t \zeta\, j^0_{\text{CS}}\ .\end{aligned}$$

Fermion Asymmetry and Free Energy

$$\partial_t N_{\rm CS} = \Gamma_+ - \Gamma_- \ , \ \frac{\Gamma_+}{\Gamma_-} = e^{-\Delta F/T}, \quad \Gamma_{\rm sph} \equiv \frac{\Gamma_+ + \Gamma_-}{V},$$





$$\partial_\mu j_i^\mu = \mathcal{N}_i^G \frac{\alpha}{8\pi} G^a_{\mu\nu} \tilde{G}^{\mu\nu,\ a} \qquad \delta n_i = \frac{\mathcal{N}_i^G}{V} \times \delta N_{\rm CS}$$

$$F_i \sim \int \frac{d^3 k}{(2\pi)^3} \left[\log\left(1 + e^{-(E-\mu_i)/T}\right) + (\mu_i \to -\mu_i) \right]$$

$$F_i \supset \frac{3V}{g_i T^2} n_i^2 \implies \Delta F_i = 12 \mathcal{N}_i^G \frac{n_i}{g_i T^2}$$

Boltzmann Equations for Asymmetries

- $\dot\theta$ is the only source term.
- $n_i \propto \dot\theta$.

For LH quarks:

$$Y_B \sim 10^{-3} \left.\frac{\dot\theta}{T}\right|_{T\to T_{\rm EW}}$$

$$\begin{aligned}
\dot n_{q_g} + 3Hn_{q_g} &= 3\kappa_{{\rm ch},u}\min(\alpha_3, y_{u_g}^2)T\left(-\frac{n_{q_g}}{6} - \frac{n_{\bar u_g}}{3} - \frac{n_H}{4}\right)\\
&+3\kappa_{{\rm ch},d}\min(\alpha_3, y_{d_g}^2)T\left(-\frac{n_{q_g}}{6} - \frac{n_{\bar d_g}}{3} + \frac{n_H}{4}\right)\\
&+\frac{9}{2}\frac{\Gamma_w}{T^3}\left(-\frac{c_W}{3}\dot\theta T^2 - \textstyle\sum_{g'}(n_{q_{g'}} + n_{\ell_{g'}})\right)\\
&+2\frac{\Gamma_c}{T^3}\left(-\frac{1}{2}\dot\theta T^2 - \textstyle\sum_{g'}(n_{q_{g'}} + n_{\bar u_{g'}} + n_{\bar d_{g'}})\right)
\end{aligned}$$

$$q_g \to (\bar u_g, \bar d_g, \bar e_g, \ell_g)$$

Upshot : $\dot\theta(T_{\rm EW}) \approx 5\,{\rm keV} \;\to\; Y_B \approx 9\times 10^{-11}$

This veloctiy will be generated by PQ violation in the UV. In this talk we focus on IR dynamics.

Friction and Kinetic Misalignment

$$\frac{\Omega_a}{\Omega_{\rm DM}} \approx \frac{\chi_c(0)}{\frac{5}{12}\frac{\pi^2}{30}g_\star(T_{\rm eq})T_{\rm eq}^4}\frac{\omega_{\rm ESFO}}{m_a}\frac{\pi^2}{3}\left(\frac{g_\star(T_{\rm eq})}{g_\star(T_{\rm ESFO})}\right)^{3/4}\left(\frac{T_{\rm eq}}{T_{\rm ESFO}}\right)^3 \approx 345\left(\frac{f_a}{5\times 10^7\ {\rm GeV}}\right),$$

$$\dot\Theta^2 = \omega_{\rm ESFO}^2 \exp\left\{-\int_{t_{\rm ESFO}}^{t} {\rm d}\log t'\,\gamma_{\rm roll}(t')\right\}, \qquad \frac{1}{2}f_a^2\dot\Theta^2 > \chi_c\,,$$

$$\gamma_{\rm roll} = 3 + \frac{\Upsilon_c}{H f_a^2}\,.$$

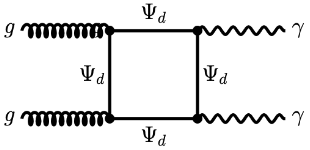
Susceptibility

$$\chi_{c,d}(T) \approx \chi_{c,d}(0) \left(\frac{\Lambda_{c,d}}{T}\right)^{\frac{11}{3}N_{c,d}-4} \prod_{m_{q_{c,d}}<T} \left(\frac{\max\left\{m_{q_{c,d}}, \Lambda_{c,d}\right\}}{T}\right)^{1/3}, \qquad T > \Lambda_{c,d}\,,$$

Quarks and Glueballs

Quark	SM Charges	Principal Role
ψ_d	(1,1,0)	Absorbing θ_2 overabundance
Ψ_d	$(1,1,\mathfrak{q}_d)$	Depleting glueballs abundance

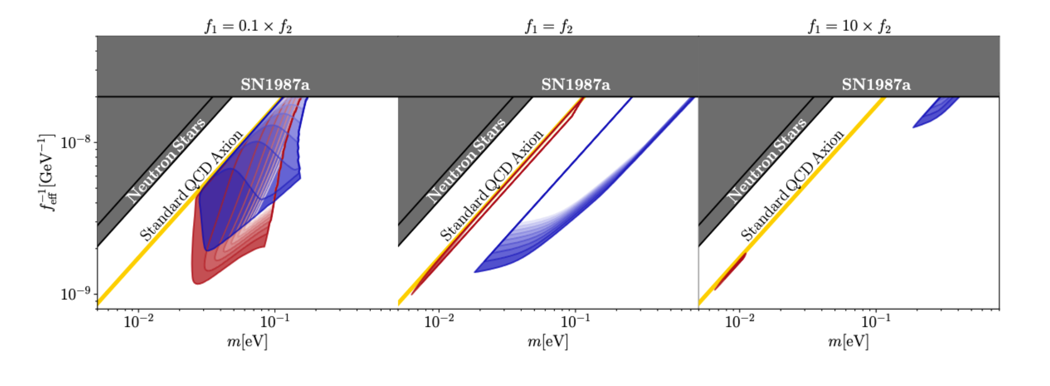
$$\tau_{0^{++}} \simeq 3600 \frac{32\pi}{(N_d^2-1)\,\mathfrak{q}_d^4\,\alpha_{\rm em}^2\alpha_d^2(m_{0^{++}})} \left(\frac{m_\Psi^3}{F^S_{0^{++}}}\right)^2 \left(\frac{m_\Psi}{m_{0^{++}}}\right)^2 \frac{1}{m_{0^{++}}},$$



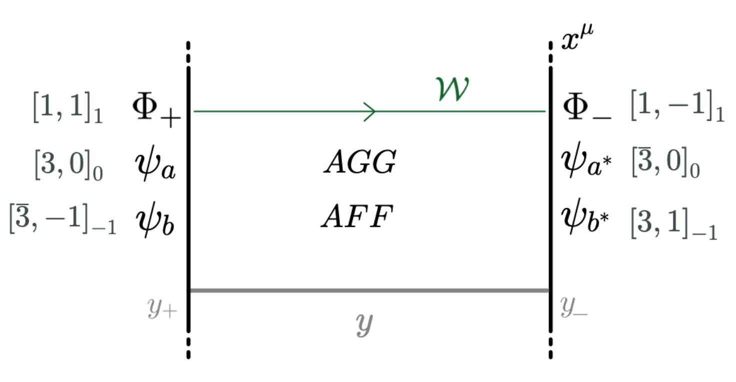
$$\tau_{0^{++}} \simeq 10^{-22}\ {\rm s} \times \left(\frac{m_\Psi}{\Lambda}\right)^8 \times \left(\frac{1\ {\rm GeV}}{\Lambda}\right)$$

Other IR Scenarios

We can have a different boundary condition at T_{EW}.



Speculation on a High-Quality UV Completion



$$\mathcal{W} = \Phi_+ \, e^{i g_d q \int_{y_+}^{y_-} dy \, A_y} \, \Phi_-$$

$$V_{\cancel{PQ}} = \frac{(\mu_- \mu_+)^{\frac{3}{2}}}{2M} e^{-ML} \mathcal{W} + \text{h.c.} + \ldots$$

$$V = \chi_c \left(1 - \cos(\theta_1 + \theta_2)\right) + \chi_d \left(1 - \cos(\theta_2)\right) + V_{\cancel{PQ}}(\theta_2)$$

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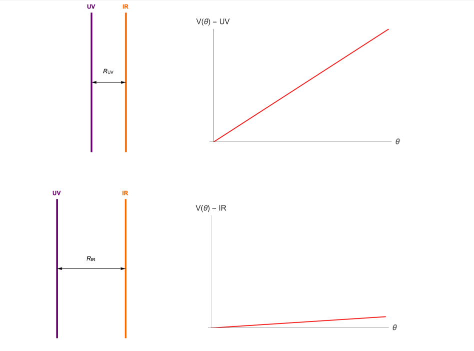

- $V_{P\!\!\!/Q}^{\mathrm{UV}} \propto e^{-MR_{\mathrm{UV}}} \sim 1$: large PQ breaking.
- R_{UV} is away from the equilibrium point of the Goldberger-Wise mechanism.
- Branes are pushed to the GW equilibrium at R_{IR}.
- $V_{P\!\!\!/Q}^{\mathrm{IR}} \propto e^{-MR_{\mathrm{IR}}} \ll 1$: negligible PQ breaking.