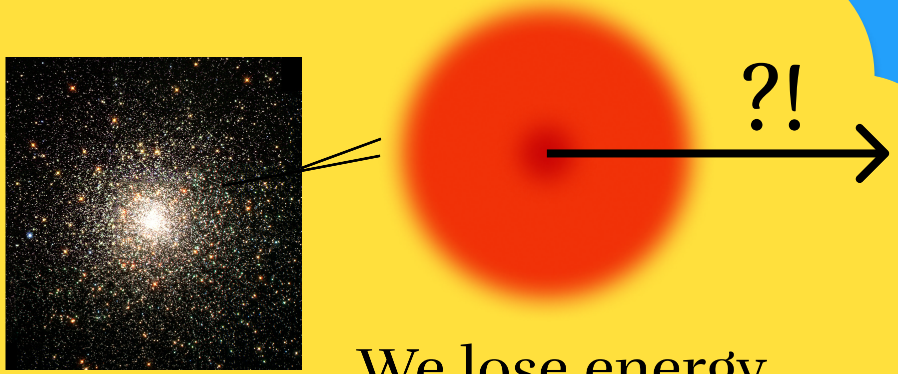
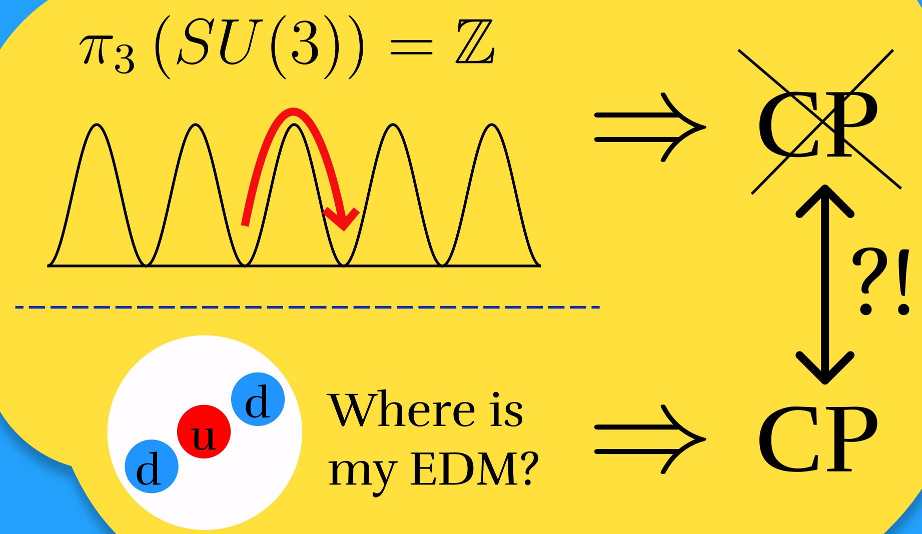
PHOTOPHILIC HADRONIC AXION FROM HEAVY MAGNETIC MONOPOLES



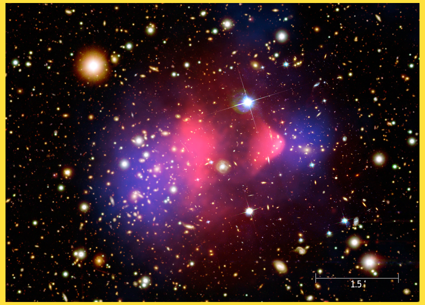
NASA&STScI image

We lose energy too fast!

One MISSED Axion Model To Explain Them All



ΛCDM

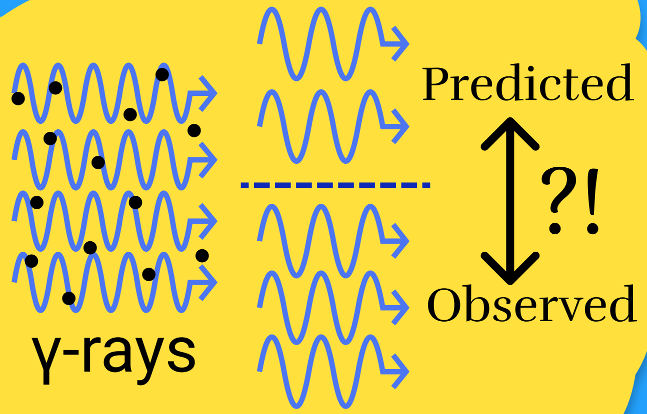


NASA image

ESO/Illustris Collaboration

What makes Cold Dark Matter ?!

NASA, ESA and J. Olmsted



PHENO 2021

05/24

Talk by Anton Sokolov based on arXiv: 2104.02574

ELECTRIC-MAGNETIC SYMMETRY OF AXION-PHOTON INTERACTION

$$\mathcal{L}_{a\gamma} = -\frac{1}{4} g^0_{a\gamma\gamma} a F\tilde{F} = g^0_{a\gamma\gamma} a \vec{E}\vec{H}$$

$$\vec{E} \leftrightarrow \vec{H}$$

KSVZ-like:

- $[U_E(1) \times SU(3)] \longrightarrow g^0_{a\gamma\gamma} a \vec{E}\vec{H}$

Let us try:

- $[U_M(1) \times SU(3)] \xrightarrow{?} -g^0_{a\gamma\gamma} a \vec{E}\vec{H}$

QUANTUM ELECTROMAGNETODYNAMICS

1894 P. CURIE

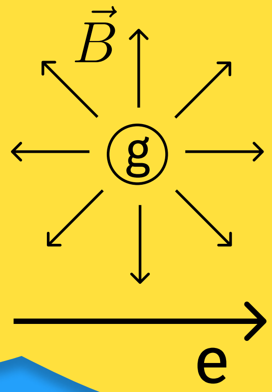
$$\nabla \cdot \mathbf{B} = 4\pi \rho_{\mathrm{m}}$$

$$-\nabla \times \mathbf{E} = \frac{1}{c}\frac{\partial \mathbf{B}}{\partial t} + \frac{4\pi}{c}\mathbf{j}_{\mathrm{m}}$$

$$\nabla \cdot \mathbf{E} = 4\pi \rho_{\mathrm{e}}$$

$$\nabla \times \mathbf{B} = \frac{1}{c}\frac{\partial \mathbf{E}}{\partial t} + \frac{4\pi}{c}\mathbf{j}_{\mathrm{e}}$$

1931 DIRAC



QM:

$$eg = 2\pi n, \;\; n \in \mathbb{Z}$$

1971 ZWANZIGER

A_μ **and** B_μ $\longleftrightarrow$ photon

$$\mathcal{L} \; = \; \mathcal{L}_{\mathrm{kin}}\left(A_\mu, B_\mu, n_\mu\right) \; - \; j_e^\nu A_\nu \; - \; j_m^\nu B_\nu$$

1977 ZBN

$$Z\left(a, b, \cancel{n_\mu}\right) = \int \exp\left\{i\left(\mathcal{S}[\mathbf{A}_\mu, \mathbf{B}_\mu, \mathbf{n}_\mu, \chi, \bar{\chi}] + j_e a + j_m b\right)\right\} \times \mathcal{D}\mathbf{A}_\mu \, \mathcal{D}\mathbf{B}_\mu \, \mathcal{D}\chi \, \mathcal{D}\bar{\chi}$$

MODEL WITH ABELIAN MONOPOLE: THEORY

$$\bullet\,[U_M(1)\times SU(3)] \longrightarrow g^0_{a\gamma\gamma}\, a\vec{E}\vec{H}$$

$$\bullet = \psi$$

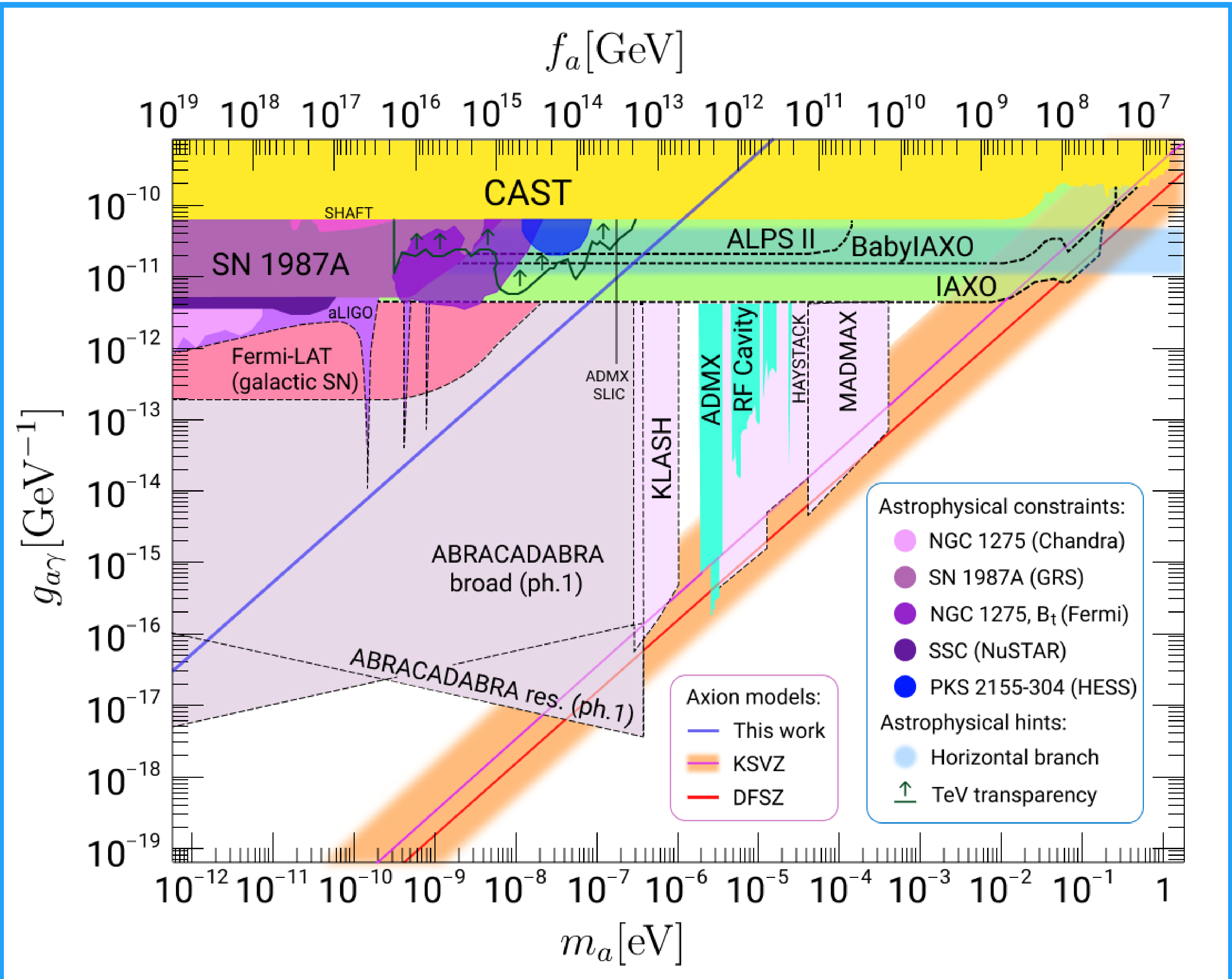
$$\mathcal{L} \supset i\bar{\psi}\gamma^\mu\partial_\mu\psi + g\bar{\psi}\gamma^\mu B_\mu\psi + y\left(\Phi\,\bar{\psi}_L\psi_R + \text{h.c.}\right) - \lambda_\Phi\left(|\Phi|^2 - \frac{v_a^2}{2}\right)^2$$

$\min\{g\} = 6\pi/e$

$$\Phi = v_a + \sigma + ia \;\Rightarrow\; \mathcal{L} \supset i\bar{\psi}\gamma^\mu\partial_\mu\psi + g\bar{\psi}\gamma^\mu B_\mu\psi + \frac{yv_a}{\sqrt{2}}\bar{\psi}\psi + \frac{iy}{\sqrt{2}}a\bar{\psi}\gamma_5\psi$$

$$\mathcal{L}_{\text{eff}} \supset \frac{iyg^2}{\sqrt{2}}a\left\langle B\left|\bar{\psi}(x)\gamma_5\psi(x)\right|B\right\rangle = -\frac{a}{16\pi^2 v_a}\cdot\frac{27}{\alpha^2}e^2\vec{E}\vec{H}$$

MODEL WITH ABELIAN MONOPOLE: PHENOMENOLOGY



MODEL WITH NON-ABELIAN MONOPOLE: THEORY

GNO conjecture: $G_M = (G_E)^V$, $g_m = 2\pi/g_s$

$(U(1))^V = U(1)$ | $(SU(3)/\mathbb{Z}_3)^V = SU(3)$

- $[U_M(1) \times SU_M(3)]$ $\quad C_\mu = gB_\mu + g_m B^a_\mu t^a$ | $\min\{g\} = 2\pi/e$

$$\mathcal{L} \supset i\bar{\psi}\gamma^\mu\partial_\mu\psi + \bar{\psi}\gamma^\mu C_\mu\psi + y\left(\Phi\,\bar{\psi}_L\psi_R + \text{h.c.}\right) - \lambda_\Phi\left(|\Phi|^2 - \frac{v_a^2}{2}\right)^2$$

Strong CP

$SU(3) \to U(1)^2$: $\quad \mathcal{G}^\alpha_{\mu\nu} \equiv (\partial \wedge A^\alpha)_{\mu\nu}$

$$\mathcal{S}_{\text{QCD}} \supset \frac{\bar{\theta} g_s^2}{32\pi^2}\int d^4x \sum_{\alpha=3,8} \mathcal{G}^\alpha_{\mu\nu}\tilde{\mathcal{G}}^{\alpha\,\mu\nu} + \frac{a g_{\text{m}}^2}{32\pi^2 v_a}\int d^4x \sum_{\alpha=3,8} \mathcal{G}^\alpha_{\mu\nu}\tilde{\mathcal{G}}^{\alpha\,\mu\nu}$$

Low energy physics

$$\mathcal{L}_{\text{eff}} \supset -\frac{1}{4} g^0_{a\gamma}\, a\, F_{\mu\nu}\tilde{F}^{\mu\nu} - \frac{a g_s^2}{32\pi^2 f_a} G^a_{\mu\nu}\tilde{G}^{a\,\mu\nu} + \mathcal{L}_{\text{off}}$$

$\mathcal{L}_{\text{off}} \to$ 0 in IR

$$g^0_{a\gamma} = 3\alpha_s^2/(\pi\alpha f_a)$$

MODEL WITH NON-ABELIAN MONOPOLE: PHENOMENOLOGY