

GPPU Progress Report

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Particle Theory and Cosmology Group

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Outline

- **Required Credits**
- **Academic activities**
- **My Current Research Project**

Required Credits

- **GPPU seminar**

- GSP 10 + GASP 4 (14/30)

- **GPPU school**

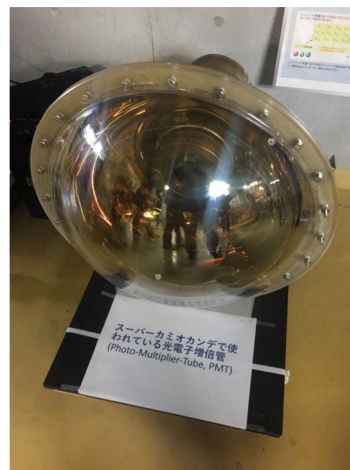
- SNP (Strangeness Nuclear Physics) School 2017

- **Overseas Institute (Germany, 5/29-7/04)**

- Visit TUM, host by Prof. Alejandro Ibarra
- Give a seminar talk about my work at MPI (6/28)
- Attend the workshop "Axion Wimp 2018" at Hamburg (6/18-6/22)

Academic Activities

- International school for Strangeness Nuclear Physics
2017 at J-PARC (12/14-12/16)



Academic Activities

- **The 3rd Winter Toyama Mini-Workshop on Particle Physics and Cosmology "Basis of the Universe with Revolutionary Ideas 2018 (BURI2018)" (01/16-01/17)**



**Buri
Shabu-
Shabu**



**Toyama
castle**

My Current Research Project

● Research Topic : Axions

- The strong CP problem in QCD

$$\mathcal{L}_\theta = \theta \frac{g_s^2}{32\pi^2} G^{a\mu\nu} \tilde{G}_{\mu\nu}^a \longrightarrow |\theta| < 10^{-10}$$

Neutron electric dipole moment Unnaturalness?

Why θ is so small is the strong CP problem.

$$\bar{\theta} \equiv \theta - \arg \det (M_u M_d)$$

Different physical sources

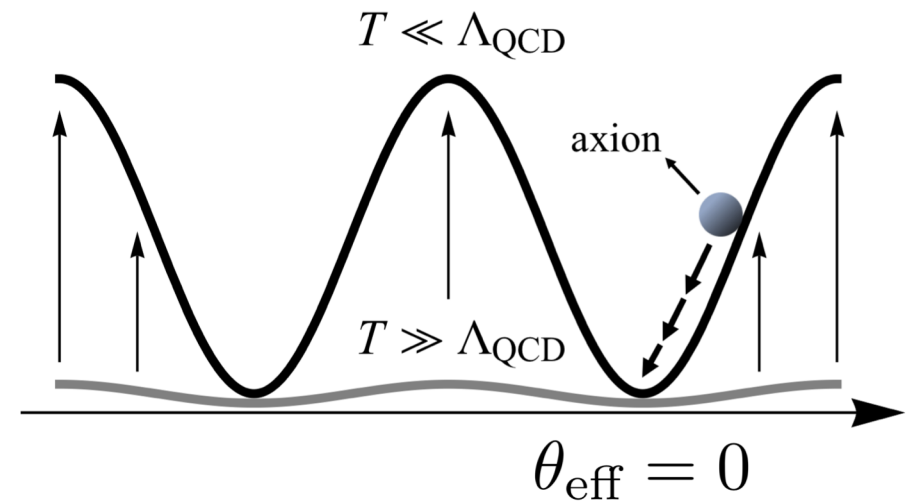
My Current Research Project

● Research Topic : Axions

- The PQ (Peccei-Quinn) mechanism

$$\mathcal{L}_\theta = \underbrace{\left(\theta + \frac{a}{f_a} \right)}_{\theta_{\text{eff}}} \frac{g_s^2}{32\pi^2} G^{a\mu\nu} \tilde{G}_{\mu\nu}^a$$

The strong CP phase is promoted to a dynamical variable.



My Current Research Project

● Research Topic : Axions

• Relic abundance of the QCD axion DM

$$\Omega_a h^2 \simeq 0.11 \theta_i^2 C(\theta_i) \left(\frac{f_a}{5 \times 10^{11} \text{ GeV}} \right)^{1.184}$$

• The axion-photon coupling

$$\mathcal{L}_{a\gamma\gamma} = \frac{g_{a\gamma\gamma}}{4} a F_{\mu\nu} \tilde{F}_{\mu\nu} = -g_{a\gamma\gamma} a \vec{E} \cdot \vec{B}$$

$$g_{a\gamma\gamma} = \frac{\alpha}{2\pi f_a} \left(\frac{E}{N} - 1.9 \right)$$

E and N are EM and color anomaly factors of the PQ current.

My Current Research Project

● Research Topic : Axions

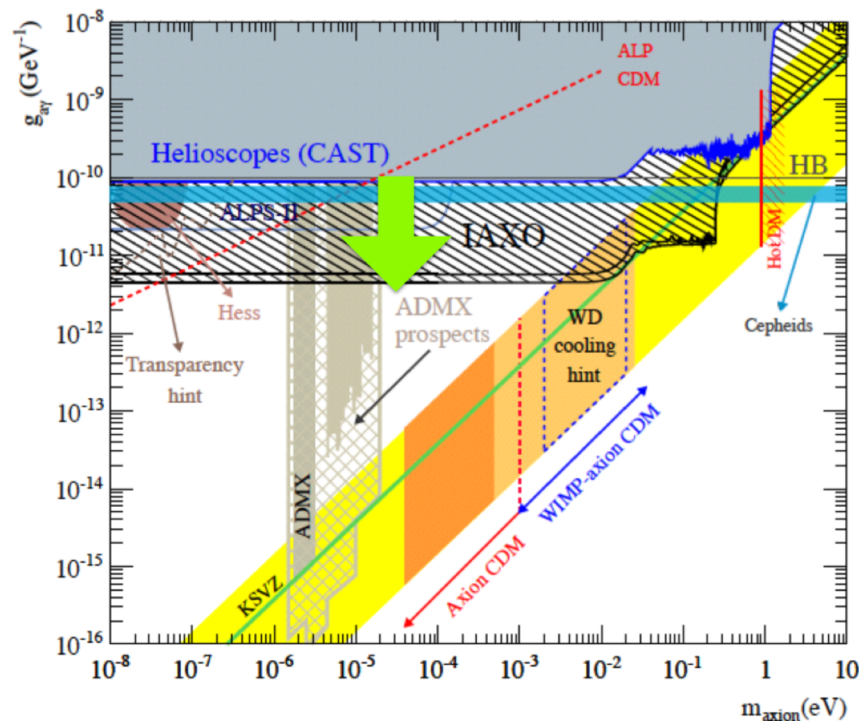


figure taken from Carosi et al, 1309.7035

Possible solutions to enhance the axion-photon coupling

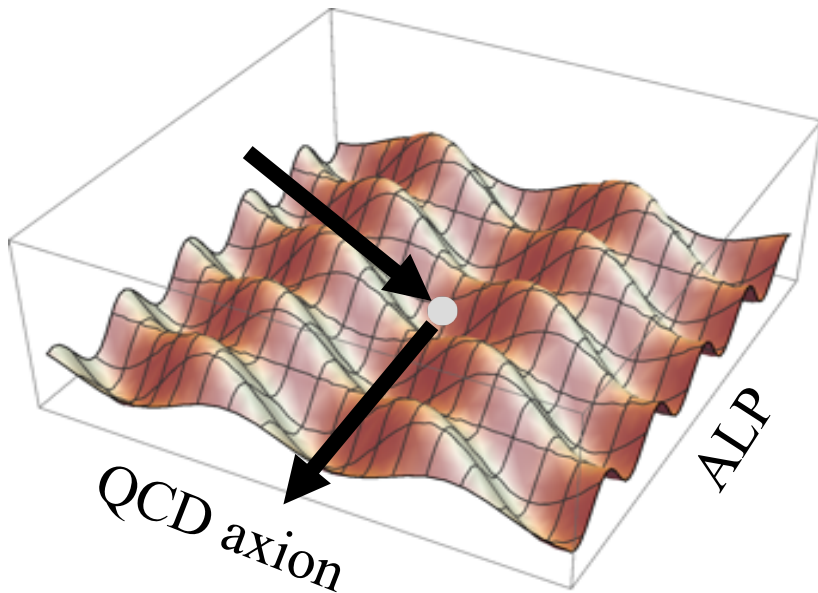
1. Clockwork axion
2. GUT with hidden photon
3. Axion-like particle (ALP)

$$V_{\text{QCD}}(a) = m_a^2(T) f_a^2 \left[1 - \cos\left(\frac{a}{f_a}\right) \right]$$

$$V_{\text{mix}}(a, \varphi) = m_\varphi^2 f_\varphi^2 \left[1 - \cos\left(\frac{a}{f_a} + \frac{\varphi}{f_\varphi}\right) \right]$$

My Current Research Project

● Research Topic : Axions



$$\Omega_{\text{DM}} \simeq \Omega_{\varphi} = \mathcal{F}(f_a)$$

$$g_{\varphi\gamma\gamma} = \frac{\alpha}{2\pi f_{\varphi}}$$

Thank you for your attention