Learning about new physics from Gravitational Waves

... and a little bit about myself

Cem Eröncel (DESY), Building 1a O1.138

14.02.2020

FH Fellow's Meeting 2020

About Me

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Hobbies:

- (Landscape) photography
- Hiking

My current work

New laboratory for fundamental physics

Gravitational waves

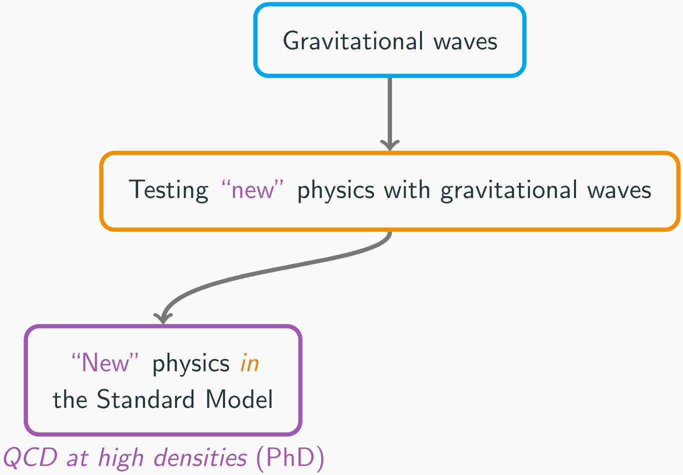
New laboratory for fundamental physics

Gravitational waves

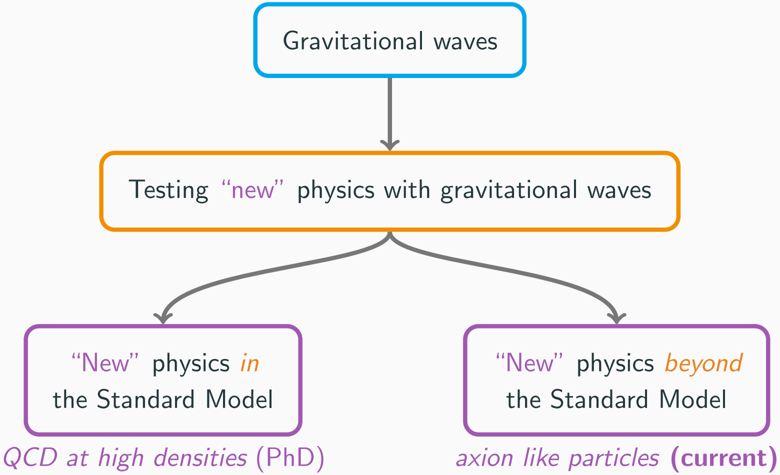
↓

Testing “new” physics with gravitational waves

New laboratory for fundamental physics



New laboratory for fundamental physics



Axions and Axion-Like-Particles (ALPs)

One of the hints of BSM: Strong CP Problem

$$\mathcal{L}_{\mathrm{SM}} \supset \frac{\theta g_s^2}{32\pi^2} G\widetilde{G}, \quad \theta \lesssim 10^{-10}.$$

The most popular solution is to add a new global symmetry to the SM.

$$\mathcal{G}(\mathrm{SM}) \otimes U(1)_{\mathrm{PQ}} \nrightarrow \mathcal{G}(\mathrm{SM}) \quad @f_a$$

Axions are the NGBs of the broken $U(1)_{\mathrm{PQ}}$.

$$\varphi = \underbrace{\chi}_{\langle\chi\rangle = \frac{f_a}{\sqrt{2}}} \exp\left\{ i\frac{\phi}{f_a} \right\}$$

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At low energy, non-perturbative physics (NP) introduces a periodic potential for the axion.

$$V \supset \Lambda\left[1 - \cos\left(\frac{\phi}{f_a}\right)\right], \quad \Lambda \equiv \text{NP scale}$$

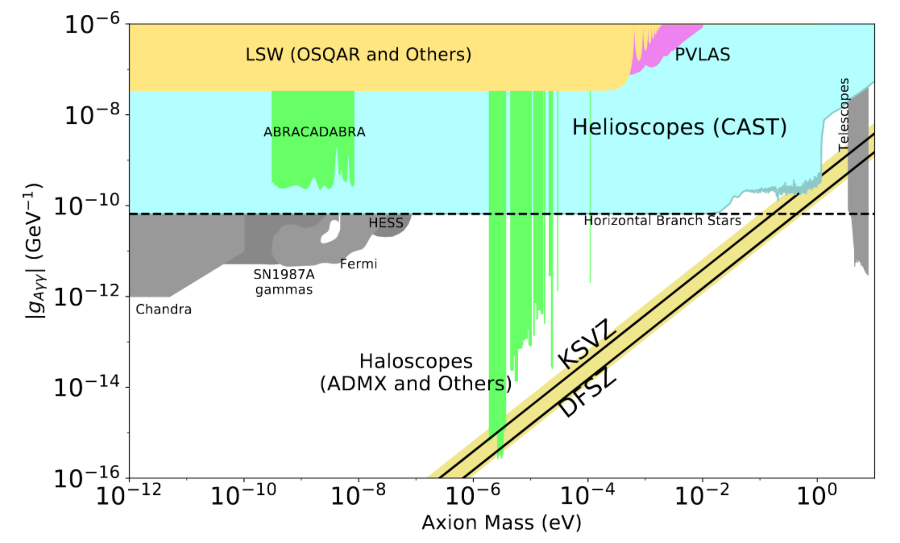
From this potential, axion gets a mass and couplings to other SM fields.

$$m^2 = \frac{\Lambda^4}{f_a^2} \quad , \quad \frac{g_{\phi\gamma\gamma}}{4}\frac{a}{f}F\widetilde{F} \sim g_{\phi\gamma\gamma}\frac{\phi}{f_a}\mathbf{E}\cdot\mathbf{B}.$$

If axions solve Strong CP, then $\Lambda \sim m_\pi^2 f_\pi^2$.

$$\Lambda \sim \begin{cases} m_\pi^2 f_\pi^2, & \text{QCD Axion} \\ \text{free parameter}, & \text{ALP} \end{cases}$$

ALP parameter space and the constraints: PDG(2019)



Axion Fragmentation

Efficient production of axion quanta is possible when an axion-like field ϕ rolls down a wiggly potential.

$$V(\phi) = -\mu^3\phi + \Lambda^4 \cos\left(\frac{\phi}{f}\right)$$

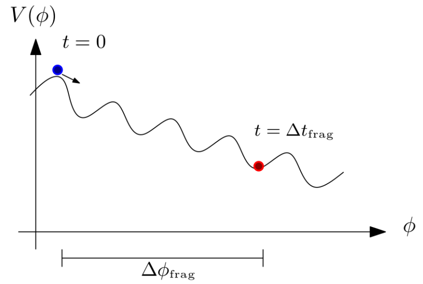
Fonseca, Morgante, Sato, Servant, 1911.08472 & 1911.08473

These axion quanta source gravitational waves:

$$\bar{h}''_{ij}(\mathbf{k}) + \left(k^2 - \frac{a''}{a'}\right)\bar{h}_{ij}(\mathbf{k}) = \frac{2a^3}{M_{\rm pl}^2}\Pi^{TT}_{ij}.$$

For this and other related models, the peak GW spectral density scales as

$$h^2\Omega_{\rm GW}(k_{\rm peak}) \sim \left(\frac{f_a}{M_{\rm pl}}\right)^n$$

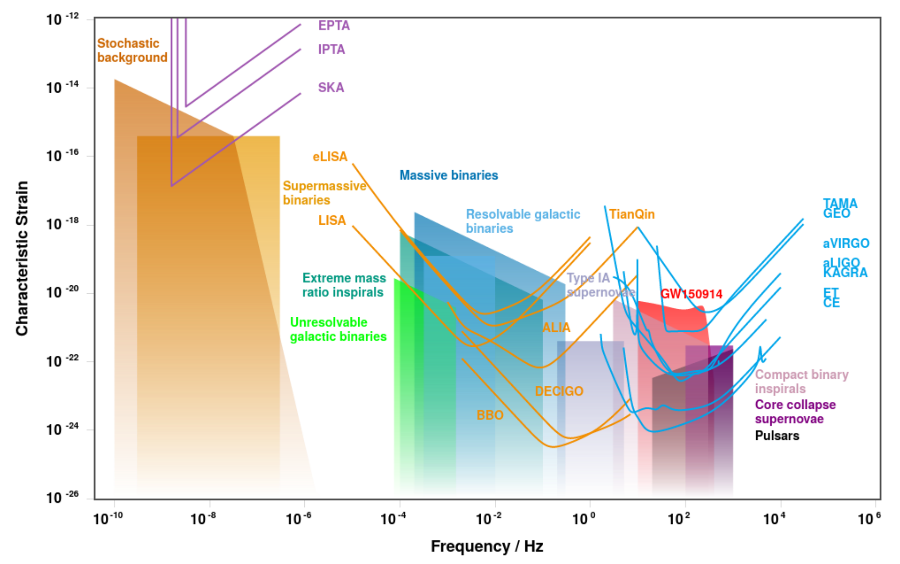


Ongoing project with Géraldine Servant, Philip Sørensen and Ryosuke Sato.

My Favourite Plot

GW sensitivity curves and sources

gwplotter.com



Thank you!

Contact:

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Theory

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