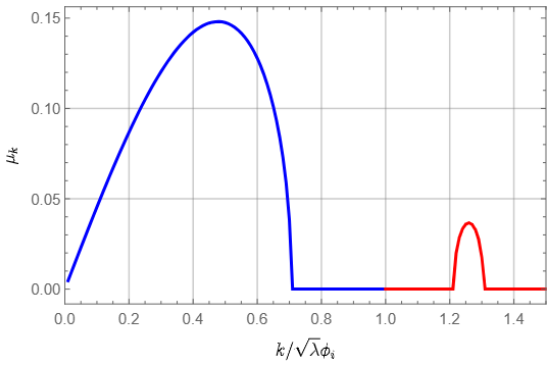
First year PhD student at **DESY Hamburg** working on **Axion phenomenology in the early universe**

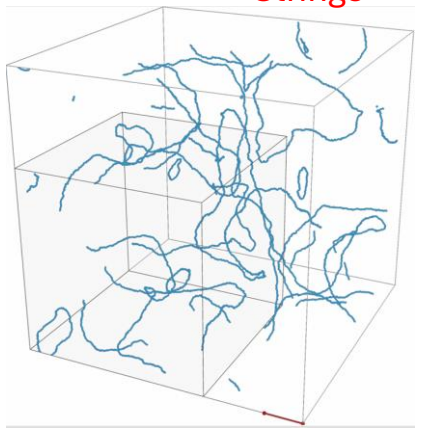
Supervisor: **Geraldine Servant**

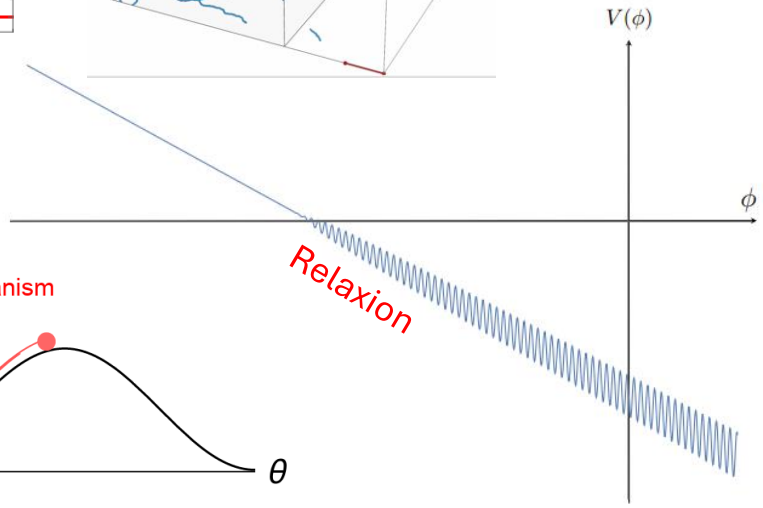
Scientific Interests:

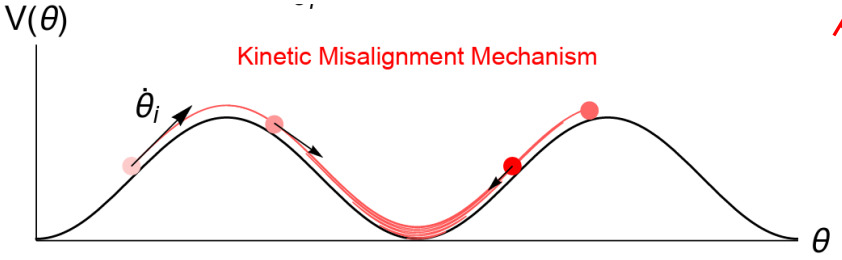
Parametric Resonance



Strings





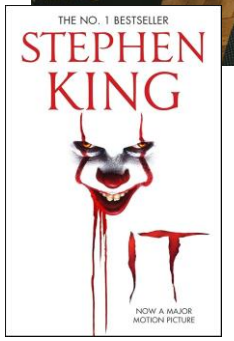


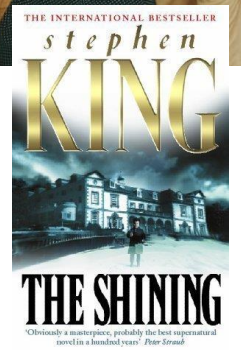
Hobbies:

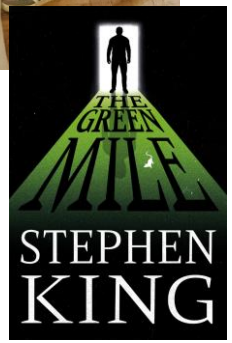
Jazz dances

Guitar

Horror books







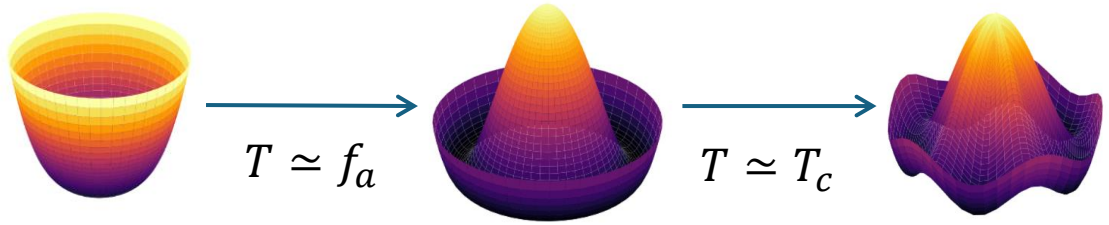
Kinetic Axion from non-minimally coupled PQ field

Enrico Morgante, Riccardo Natale 2508.XXXXX

Misalignment Mechanism

PQ symmetry restored at high energies

Symmetry breaking around the scale f_a



Explicit symmetry breaking at low energies via non perturbative effects

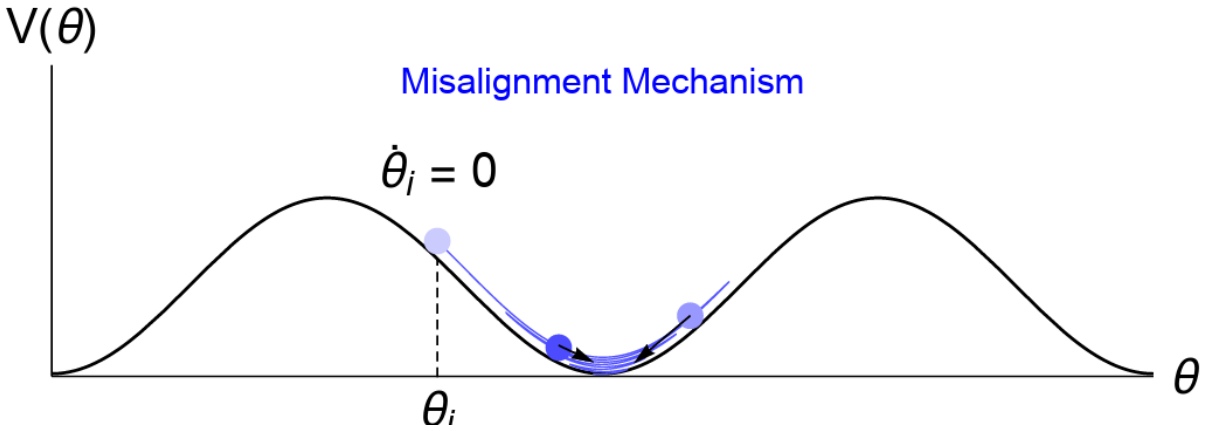
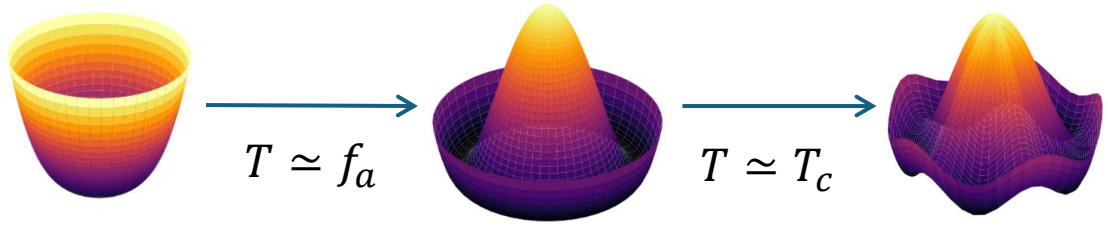


Fig. by «Harigaya et all, Axion Kinetic Misalignment Mechanism»

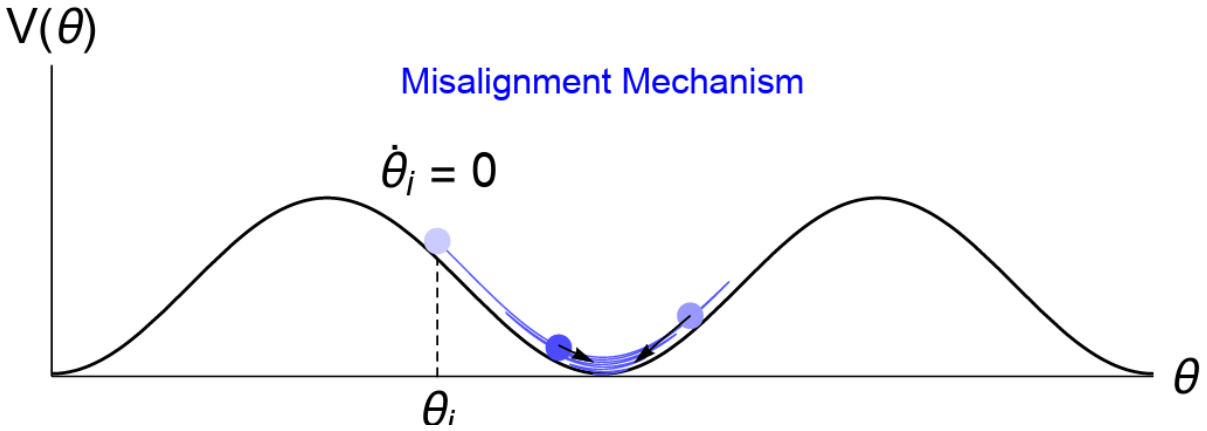
Misalignment Mechanism

PQ symmetry restored at high energies

Symmetry breaking around the scale f_a



Explicit symmetry breaking at low energies via non perturbative effects



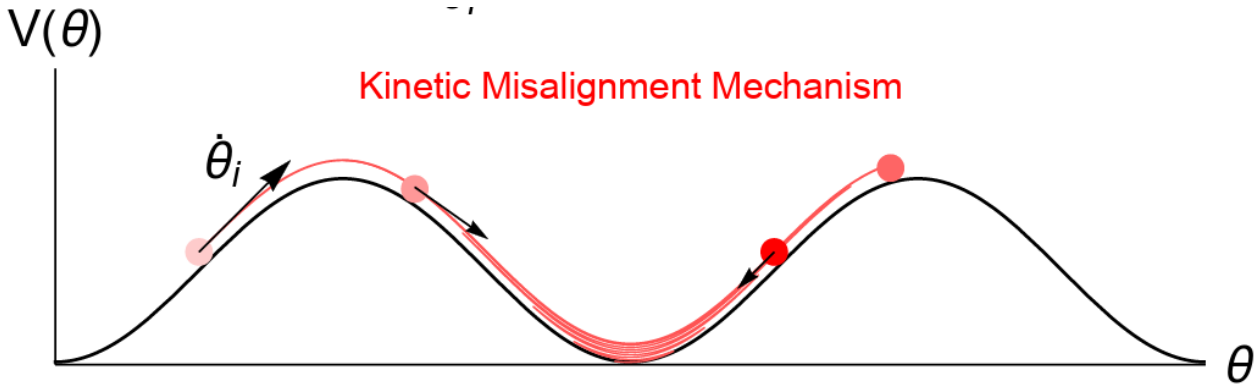


Fig. by «Harigaya et all, Axion Kinetic Misalignment Mechanism»

How to generate a large axion velocity

Kinetic Misalignment can be generated by **high-order operators** producing an **explicit breaking of U(1) symmetry**

$$V_{\not{PQ}} = 2^{\frac{n}{2}} \frac{A\Phi^n}{nM_{\rm Pl}^{n-3}} + \text{h.c.}$$

In order to make this operators relevant the radial mode has to reach **high field values**

- **Quantum Fluctuations** during inflation
- **Hubble-Induced mass**
- **Coupling with the Inflaton**

2408.17013 Lee, Menkara, Seong, Song
2408.08355 Eröncel, Sato, Servant, Sørensen
2312.17730 Co, Yamada
2310.17710 Lee, Menkara, Seong, Song
2004.00629 Co, Hall, Harigaya, Olive, Verner

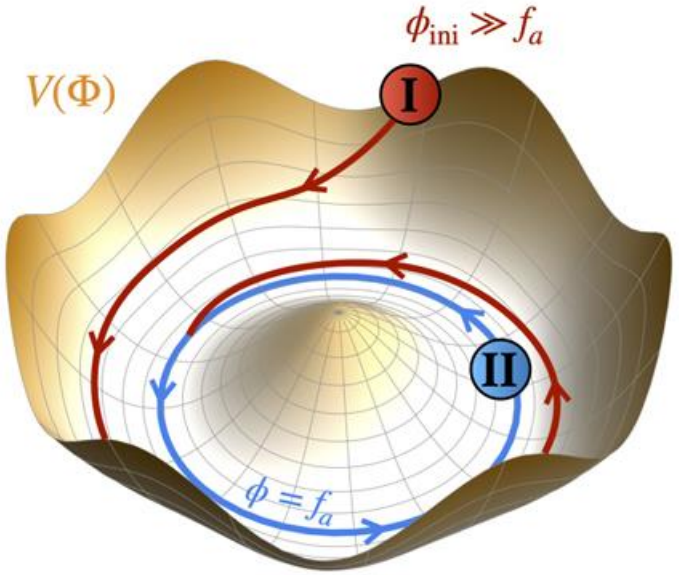


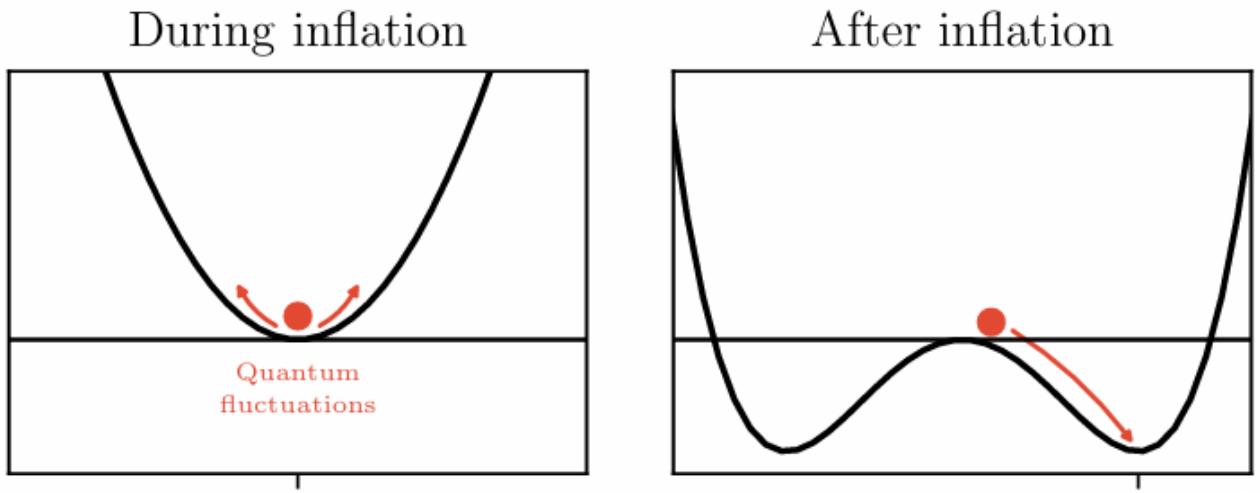
Fig. by Gouttenoire et all, «Kination Cosmology from scalar fields and gravitational waves signatures»

Kinetic Axion with NMC PQ field

$$S = \int \mathrm{d}^4x\sqrt{-g}\left[\frac{M_{\rm Pl}^2}{2}R + \mathcal{L}_{\rm inf} - g^{\mu\nu}\partial_\mu\Phi\partial_\nu\Phi^\dagger - \xi R|\Phi|^2 - V_{\rm PQ}(|\Phi|) - V_{\not{\rm PQ}}(\Phi,\Phi^\dagger)\right]$$

- A **non-minimal coupling**
- A **stiff era**

This transition generates a **tachyonic instability**



$$R = 3(1-3\omega)H^2$$

$m^2 \approx 12\xi H_I^2$ During Inflation

$m^2 \propto -H^2$ After Inflation

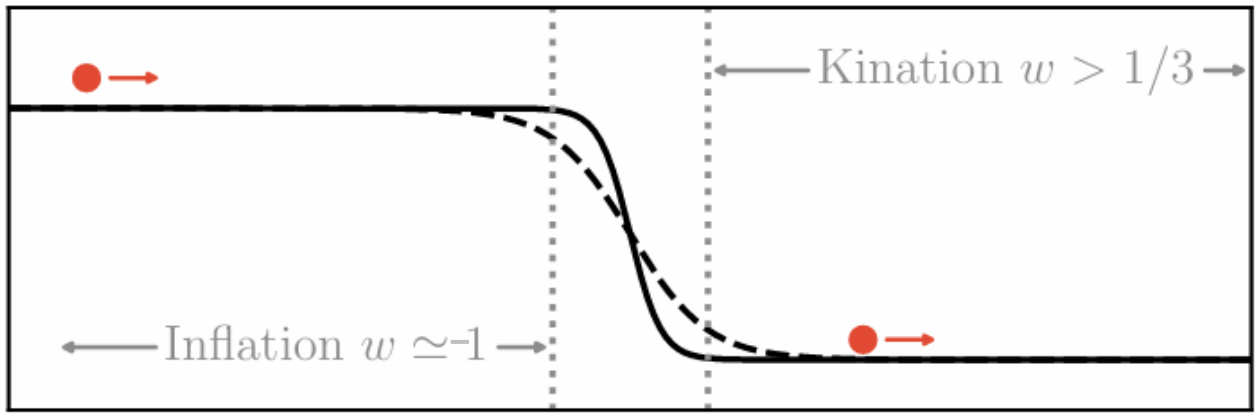
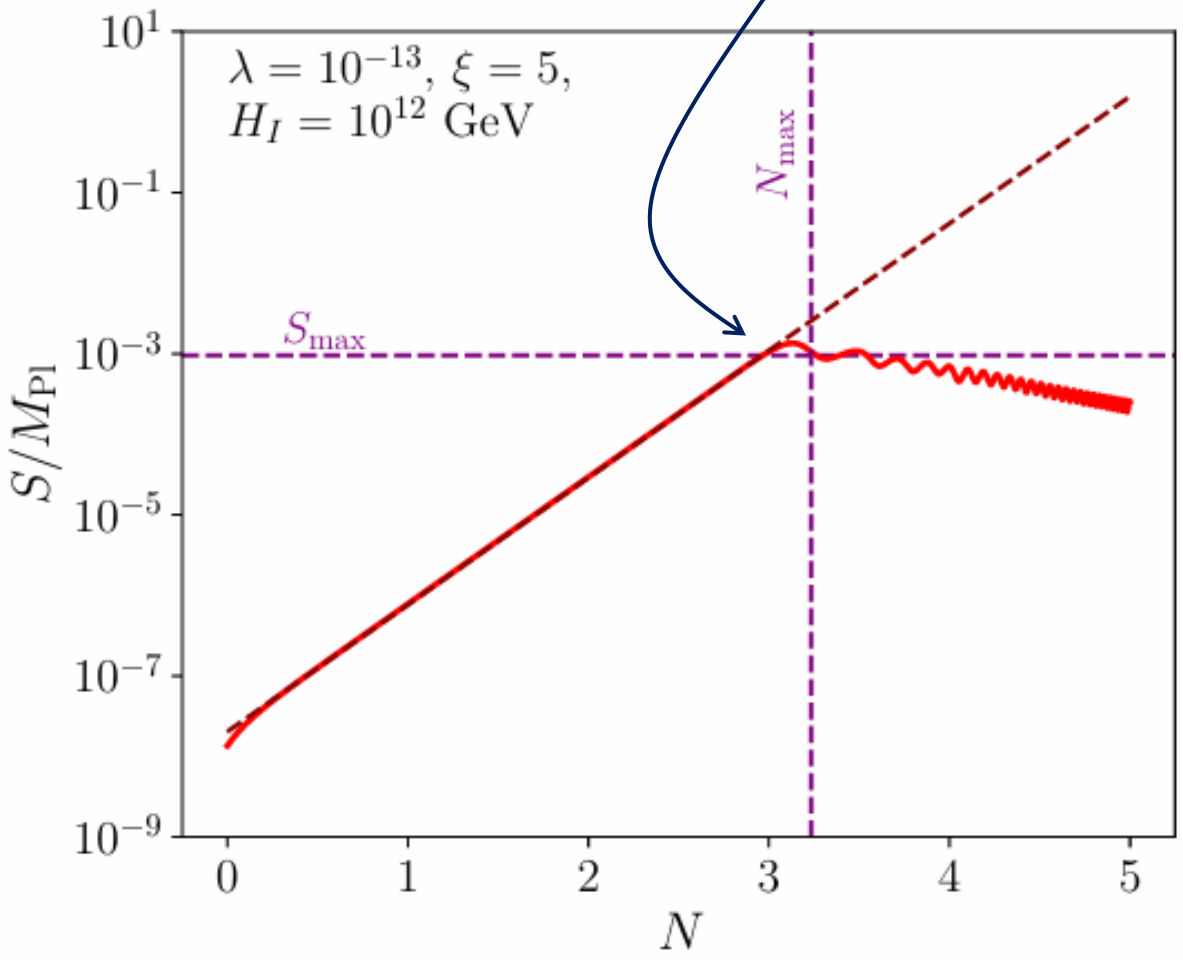
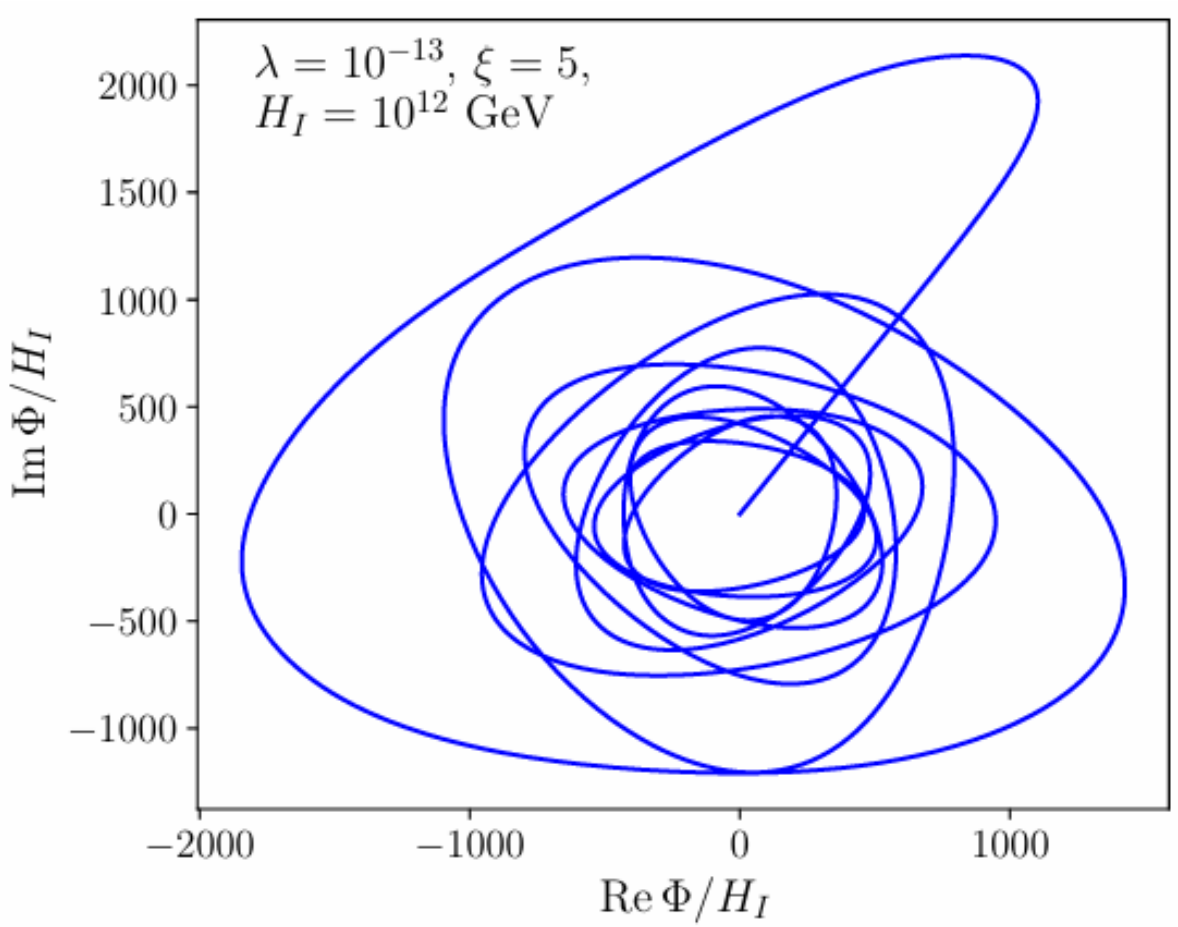


Fig. by Figueroa et all «Ricci Reheating on the Lattice»

PQ Field Dynamics

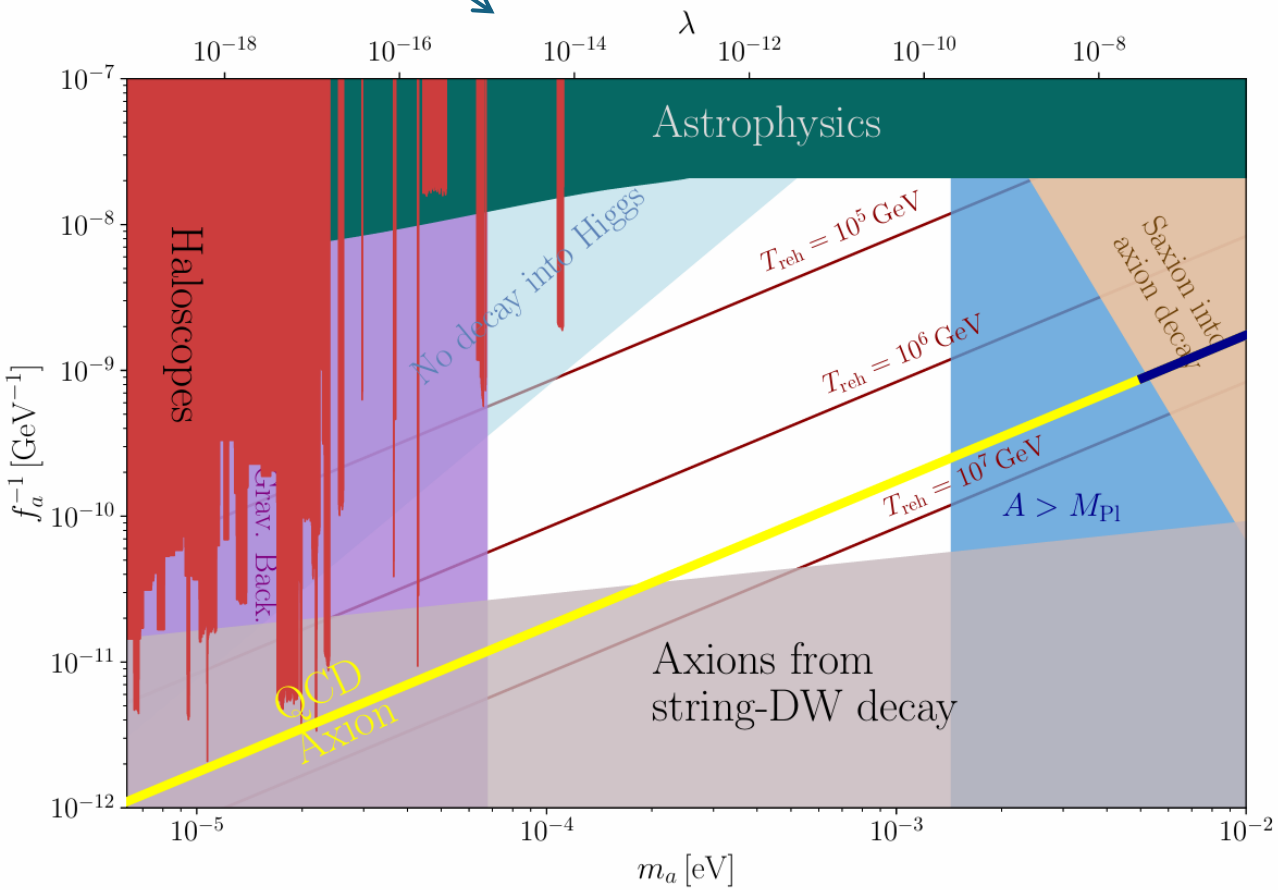
Here the field starts rotating!

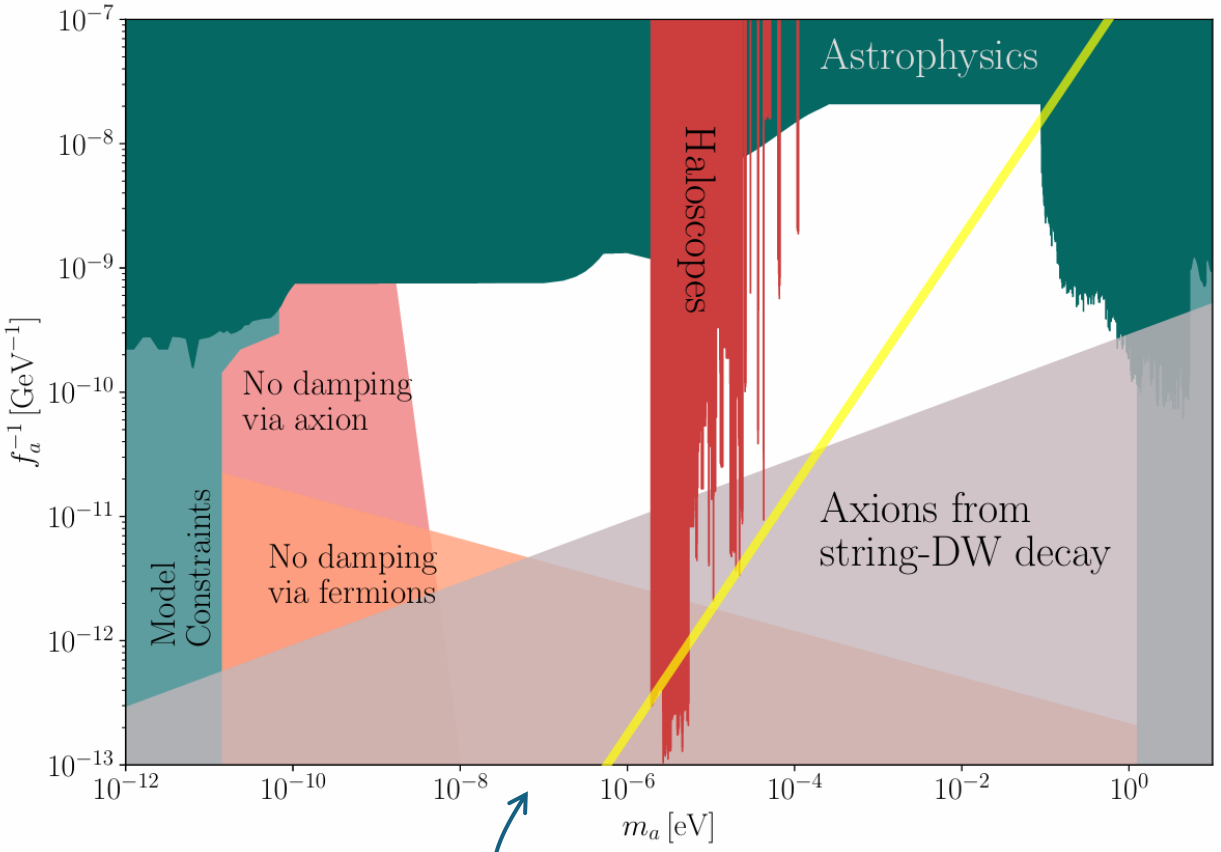




Axion Dark Matter Abundance

If the radial mode is also responsible for reheating

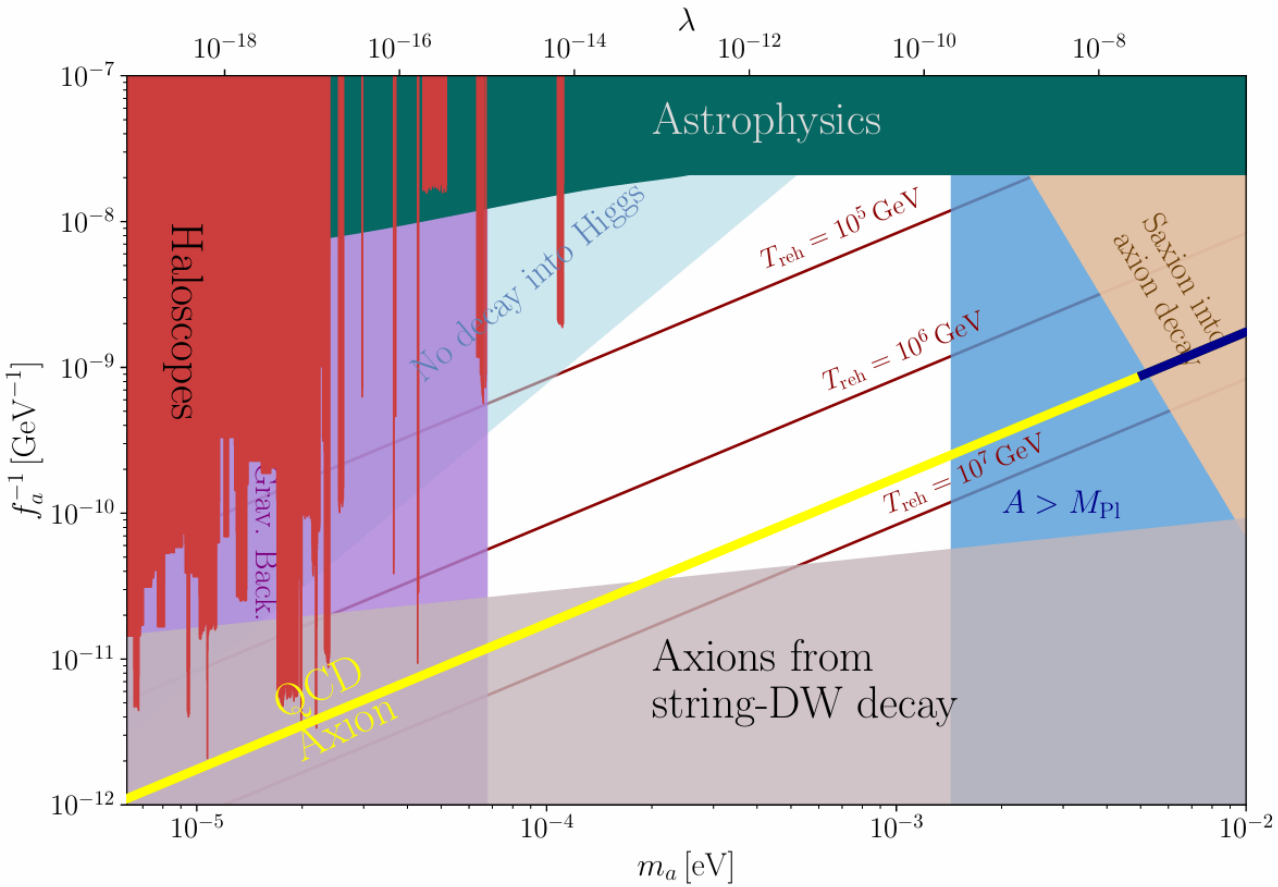


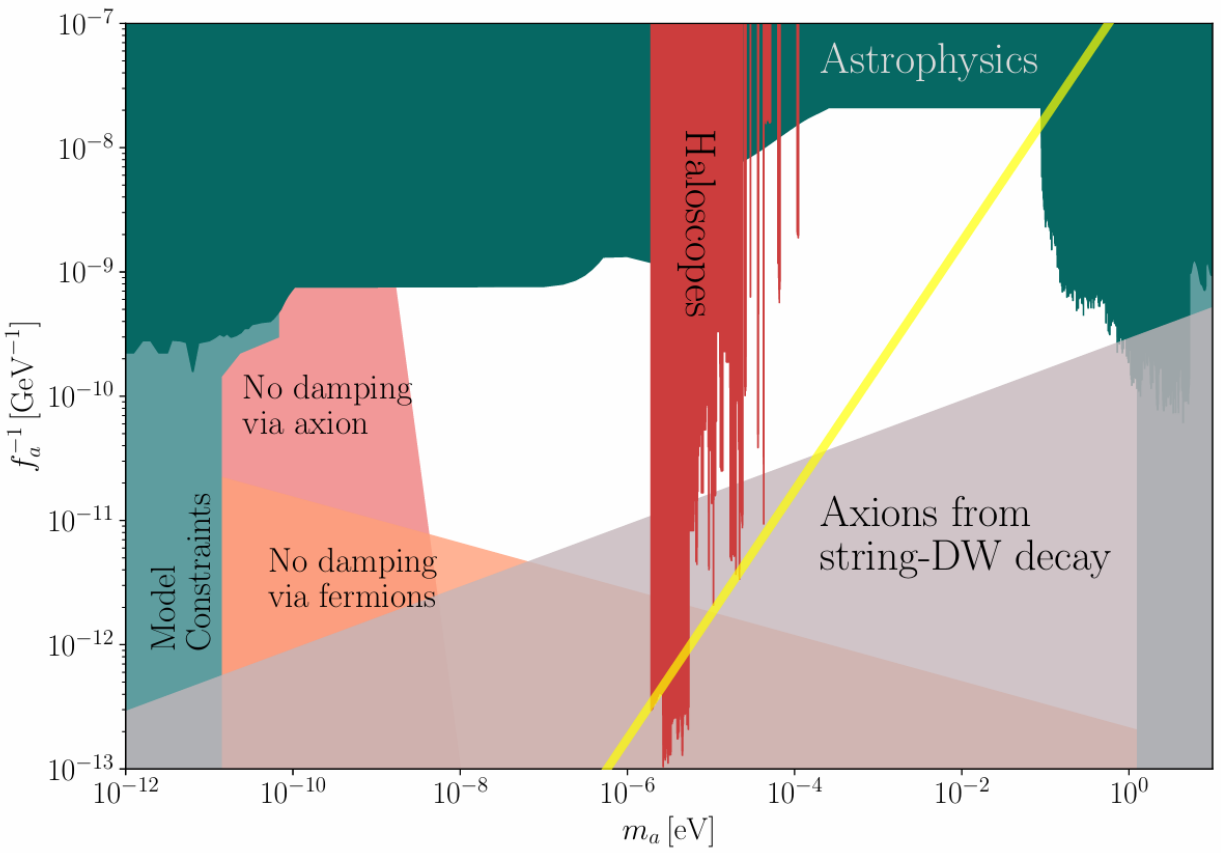


With the addition of a different reheating mechanism

Axion Dark Matter Abundance

Thank you!

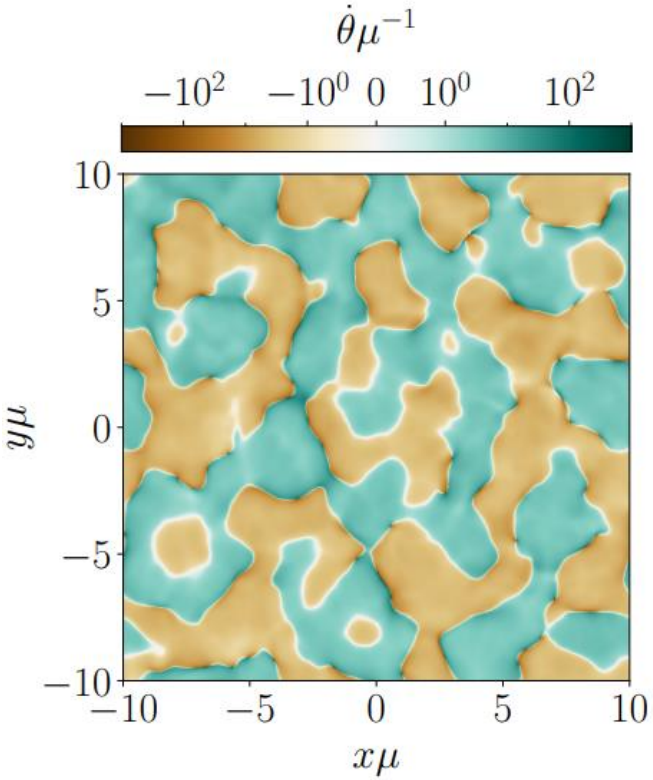




Backup Slide

Because spontaneous symmetry breaking happens **after inflation**, the axion field takes on **different values** in separate regions of the universe.

$$\dot{\theta}_{\max} = \beta \sin(n\theta) \frac{A S_{\max}^{n-2}}{M_{\mathrm{Pl}}^{n-3} H_{\max}}$$



Once the kick is applied, the universe becomes **divided into multiple domains**, each carrying a U(1) charge of either **positive** or **negative** sign.

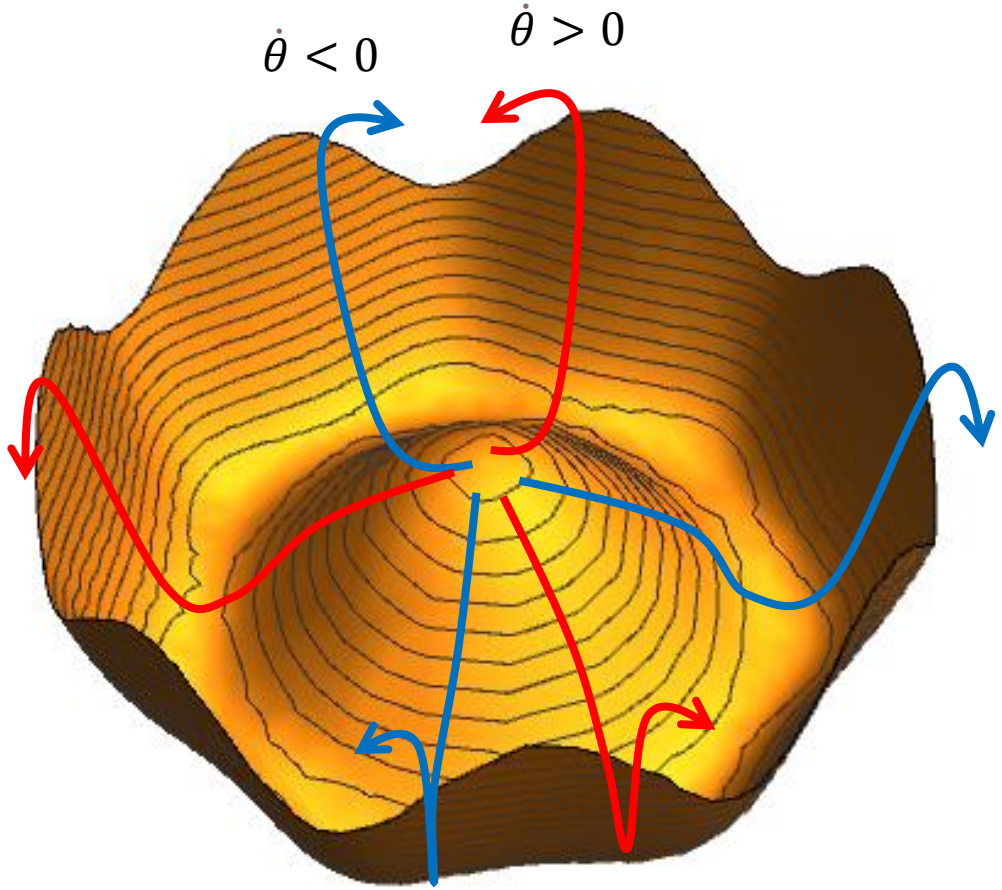


Fig. by Fedderke et all «Periodic Cosmic String Formation and Dynamics»