Journey into the axiverse:

Understanding the effect of multi-axion interactions on observables

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The String Axiverse

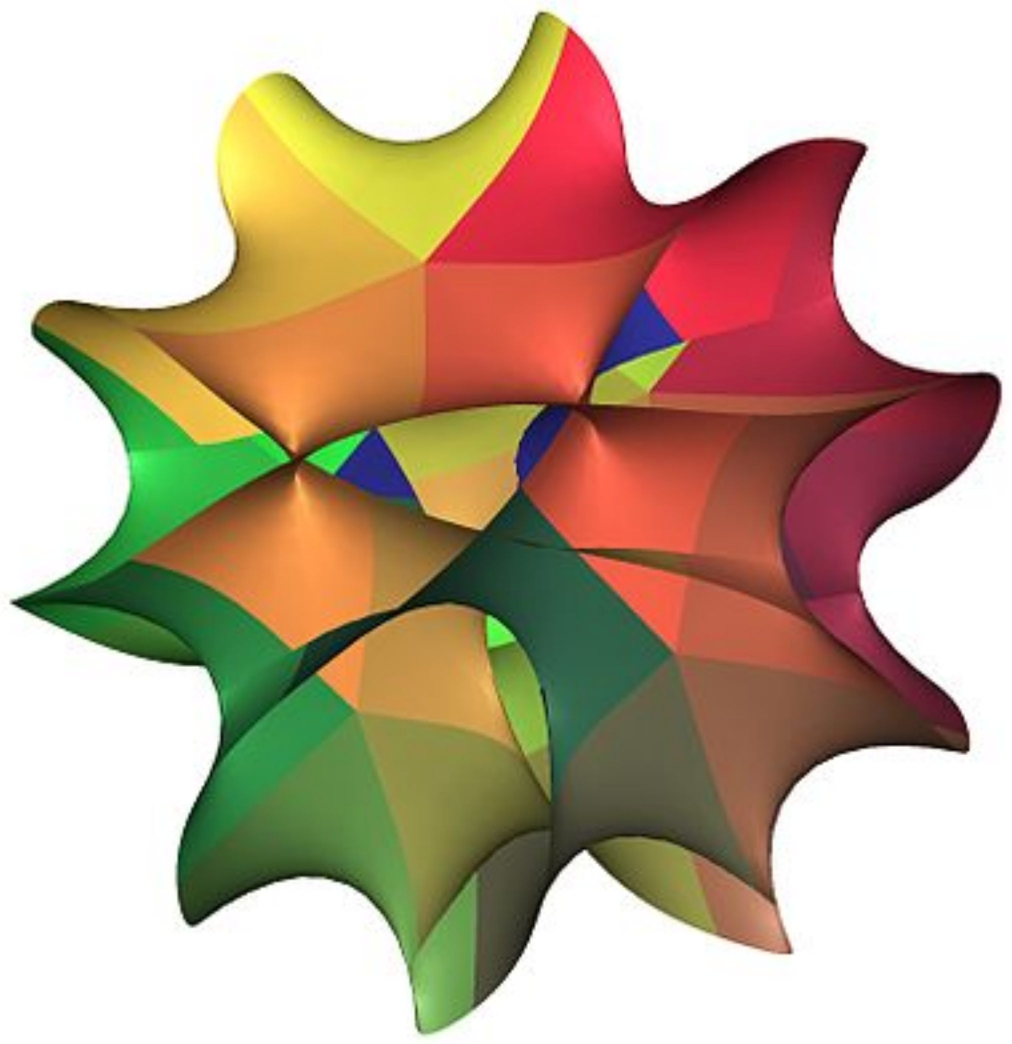


Image Credit: Andrew J. Hanson

String compactifications

Many light axions

(e.g. Arvanitaki et al. 2009)

Would like to understand how many axions and their interactions affect observables

Relic abundance from misalignment mechanism

EoM

$$\ddot{\theta} + 3H\dot{\theta} + m^2 \sin\theta = 0$$

+

Inflationary initial Conditions

$$\theta_0 \sim \text{Unif}(-\pi, \pi)$$

$$\dot{\theta}_0 = 0$$

$$\Rightarrow$$

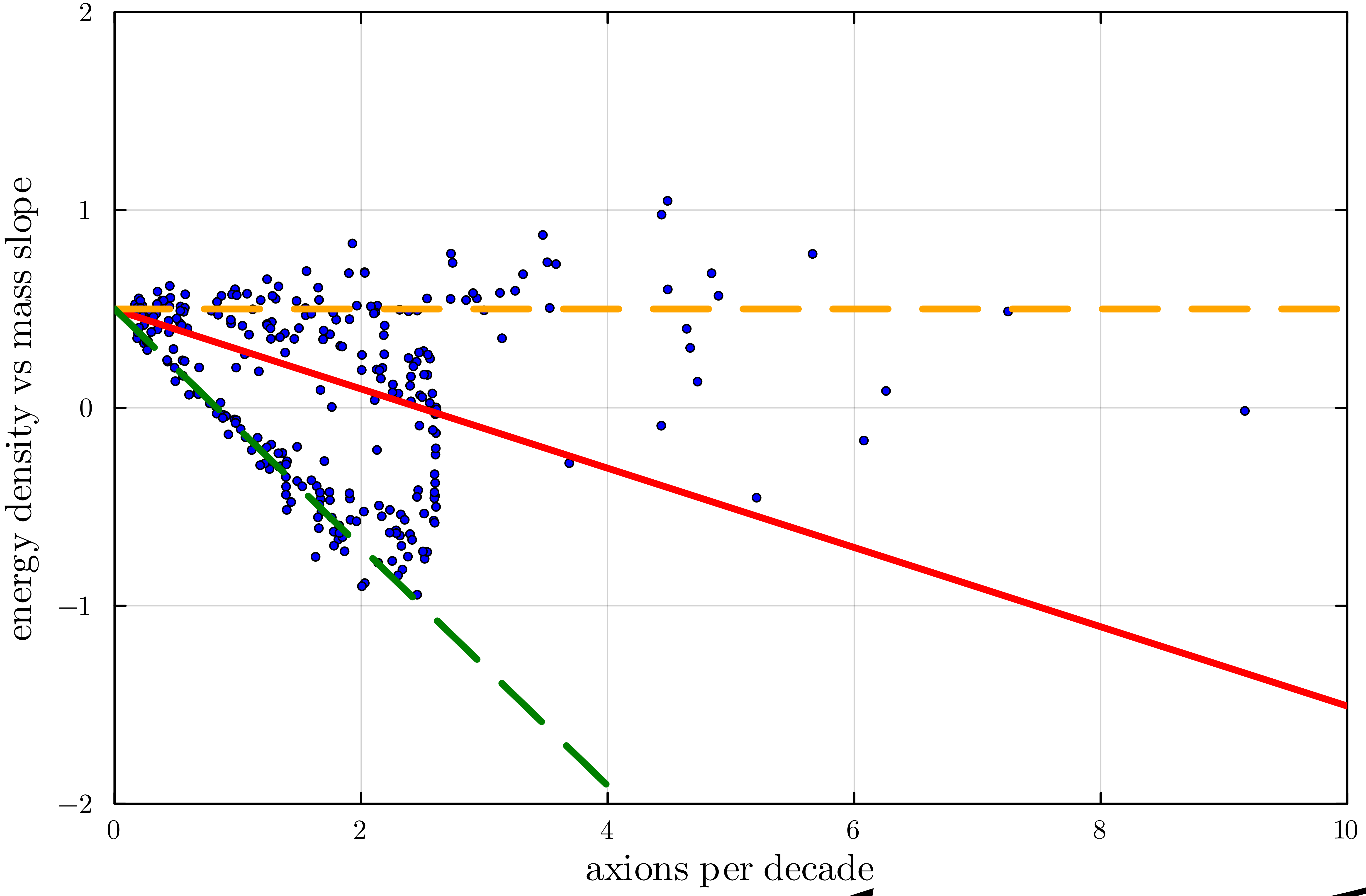
$$\Omega_a \sim \left(m/H_{eq}\right)^{1/2} \left(\theta_0 f/M_{pl}\right)^2$$

Energy densities of many axions

In the axiverse: $\mathscr{L} = \frac{1}{2} k_{ij} \partial_\mu \theta_i \partial^\mu \theta_j - \sum_{i=1}^{N} \Lambda_i^4 \left(1 - \cos\left(\sum_j n_{ij} \theta_j\right)\right)$

2 interacting axions

$$\mathscr{L} = \frac{1}{2}\partial_\mu\theta_i\partial^\mu\theta_i - \left[\Lambda_1^4\left(1-\cos(n_{11}\theta_1+n_{12}\theta_2)\right) + \Lambda_2^4\left(1-\cos(n_{21}\theta_1+n_{22}\theta_2)\right)\right]$$



$$\frac{\log\left(\Omega_2/\Omega_1\right)}{\log\left(m_2/m_1\right)}$$

$$\frac{1}{\log\left(m_2/m_1\right)}$$

Conclusions

AXIVERSE MACHINE

- Cosmological axion production is affected by the presence of many axions
  - When $N > 1$, lighter axions seem to be favored
  - For $N = 2$ with large mass separation and interactions, a change in the effective f of the heavy and light fields explains the change Ω_2/Ω_1

- **Next Steps:** regimes where dynamical energy transfer is relevant; generalized potentials; effects on observables including direct detection / astrophysical; large N

- **Other Work:** astrophysical tests of ultralight scalars and dark photons, axion-induced patchy screening of quasars, BH superradiance…

Back up

Relic abundance from misalignment mechanism

EoM: $\ddot{\theta} + 3H\dot{\theta} + m^2 \sin\theta = 0$

+

Initial Conditions:
(e.g. Graham et al. 2018)

$$p(\theta_0) \propto \exp\left(-\frac{8\pi^2 V(\theta_0)}{3H_I^4} \right)$$

$$\Omega_a \sim \left(m/H_{eq}\right)^{1/2} \left(\theta_0 f/M_{pl}\right)^2$$