PASCOS, IFT Madrid 20th June 2017

Dynamically determining the weak scale from inflation

[JCAP, 1701.09167]

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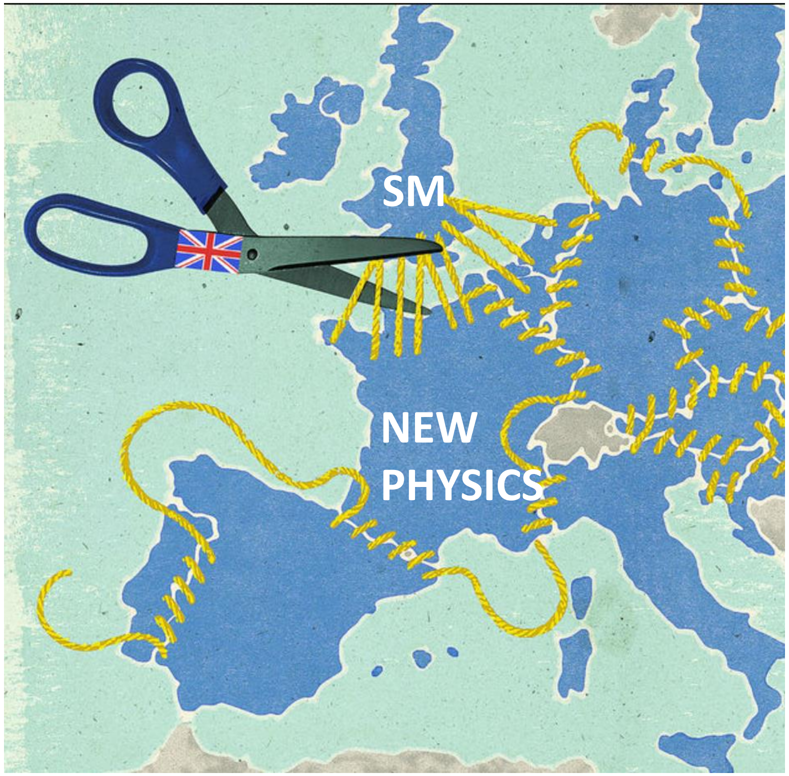
Naturalness

- Usual arguments are old and well known but **still as valid** now as back when they were made
  - After all, our understanding of QFT has not changed so why should the conclusions drawn from it be any different now?
- But what about null experimental data? The issue is with the **solutions**, not the **hierarchy problem**, which is as motivated as ever
  - Philosophical waffling about unknown priors for fine-tuning and all that matters are observables etc. are irrelevant to the fact that there is something strange going on
  - c.f. Newton: $m_{inertial} = q_{gravity}$
- Interesting to consider alternative solutions assuming a desert above the weak scale

Naturalness

- Assume new physics is decoupled (SMEXIT)



- Can we still have a naturally light Higgs mass?

Cosmological Relaxation

P. W. Graham, D. E. Kaplan and S. Rajendran, [arXiv:1504.07551]

L. F. Abbott, Phys. Lett. B 150 (1985) 427

- Higgs mass is naturally at large cut-off M

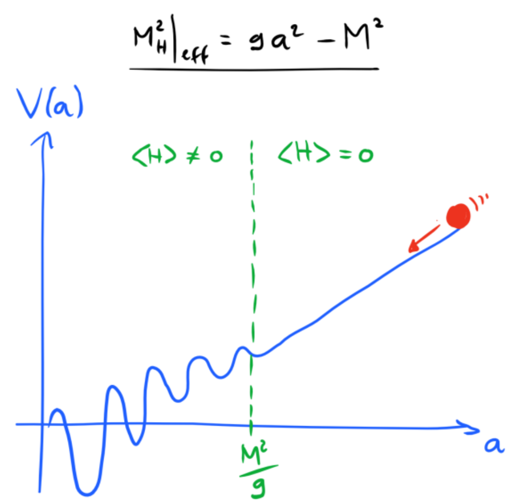
$$V_{\rm soft}(a) \simeq (ga - M^2)|h|^2 + gM^2 a + \ldots$$

- Axion-like particle *a* protected by shift symmetry, explicitly broken through technically-small parameter *g*

- Scans an effective Higgs mass

- Barriers switch on after EWSB

$$V_{\cos}(a) = \Lambda_G^4 \cos(a/f) \qquad \Lambda_G^4 \equiv \Lambda_G^{4-n} v^n$$



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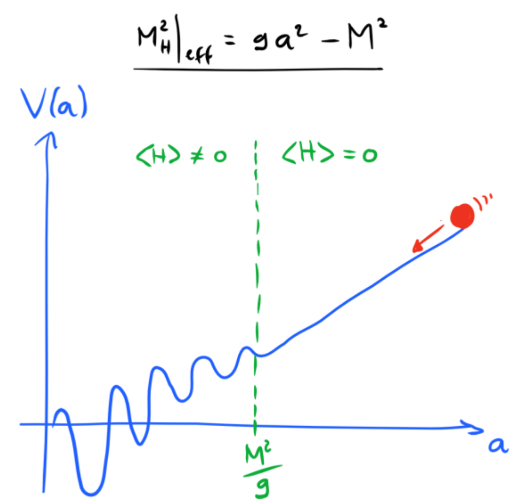

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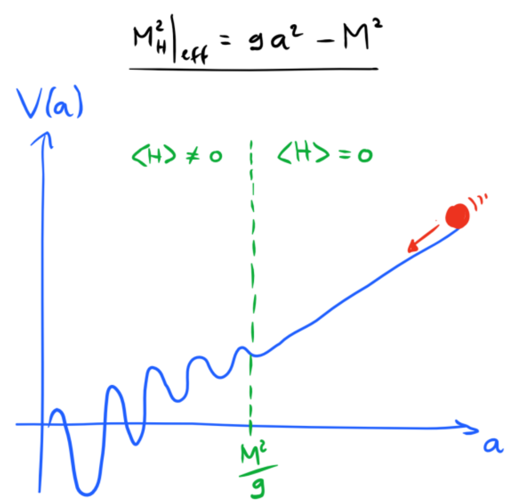

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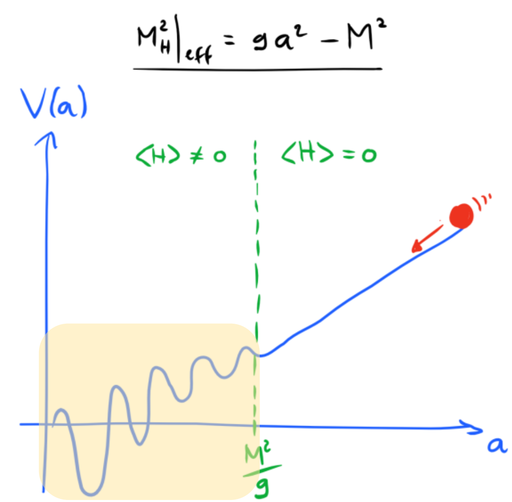

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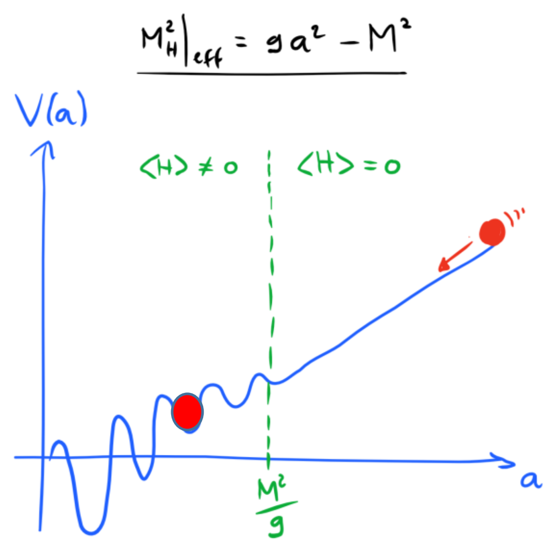
- Trapped when barrier height = slow-roll slope

$$gM^2 \sim \frac{\Lambda_G^{4-n} v^n}{f_\phi}$$

- Technically-natural for v << M



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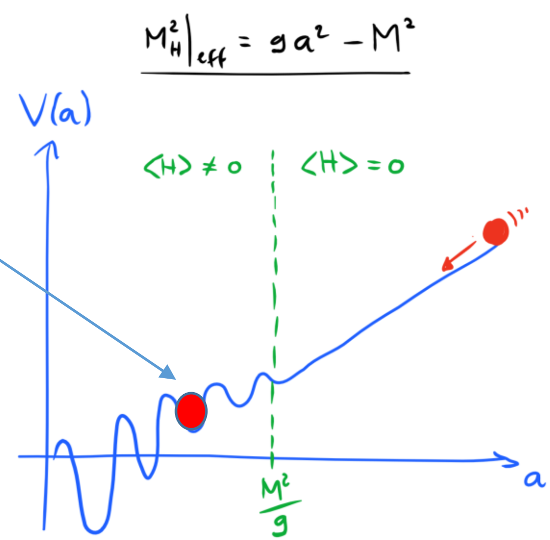

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Constraints: H < v, classical rolling vs quantum, inflaton energy density dominates relaxion, etc.

Very small *g* and natural scanning range lead to super-planckian field excursions, exponential e-foldings…

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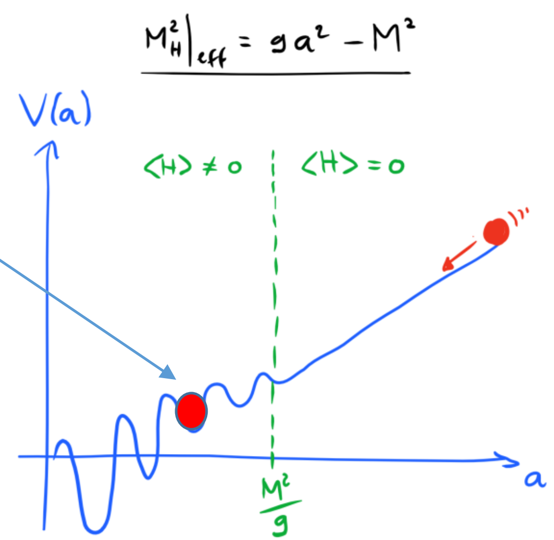

Relaxation Models

(apologies for lack of references)

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- **n=1 models** Graham et al [arXiv:1504.07551]
  - G=QCD: Theta problem
  - G=QCD with inflaton coupling: not technically natural
  - New gauge group G: new physics at weak scale + coincidence problem

- **n=2 models** Espinosa et al [arXiv:1506.09217]
  - G can be at higher scales, raises M cut-off too
  - Requires second scalar to relax relaxion barriers: double-scanning mechanism

- **n=0 models** Hook and Marques-Tavares [arXiv:1607.01786], **TY** [arXiv:1701.09167]
  - More promising, make use of axial gauge coupling

$$\mathcal{L} = \frac{1}{32\pi^2} \frac{a}{f} \epsilon^{\mu\nu\rho\sigma} \mathrm{Tr} G_{\mu\nu} G_{\rho\sigma}$$

    - (see also Toyokazu Sekiguchi talk for use of dissipation in n=1,2 models)

Relaxation backreaction on inflation

TY [arXiv:1701.09167]

- Minimal relaxion setup, **no v=dependence in relaxion sector**

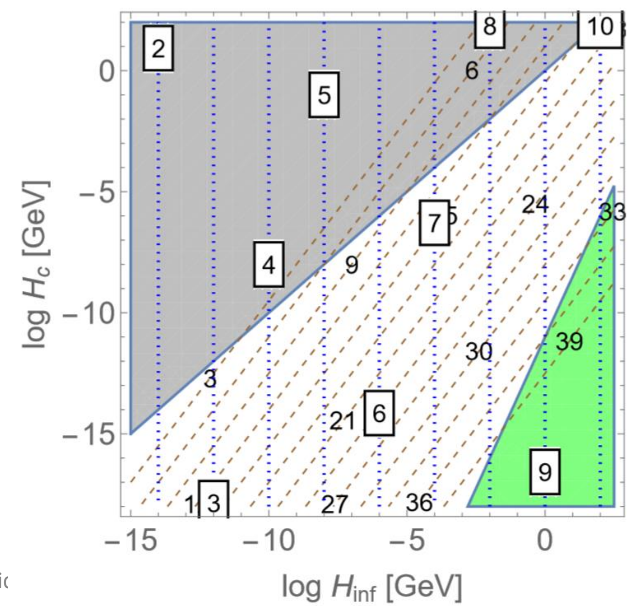
$$\mathcal{L} \supset \left(M^2 - g\phi\right)|h|^2 + gM^2\phi + ... + \Lambda_G^4 \cos\left(\frac{\phi}{f_\phi}\right) - \frac{\alpha_D}{f_D}\phi F_{\mu\nu}\tilde{F}^{\mu\nu} \,,$$

- Backreaction instead ends inflation
  - e.g. Inflation supported by electroweak dissipation $\mathcal{L} \supset -\frac{\alpha}{f}\sigma F_{\mu\nu}\tilde{F}^{\mu\nu}$

$$\ddot{\sigma} + 3H\dot{\sigma} + V'_\sigma(\sigma) = -I\frac{\alpha}{f}\left(\frac{H}{\xi}\right)^4 e^{2\pi\xi} \,, \qquad \xi \equiv \frac{\alpha}{2f}\frac{\dot{\sigma}}{H}$$

See e.g. Anber and Sorbo 0908.4089

- Hubble falls
- Dark dissipation increases
- Relaxion loses KE and is trapped



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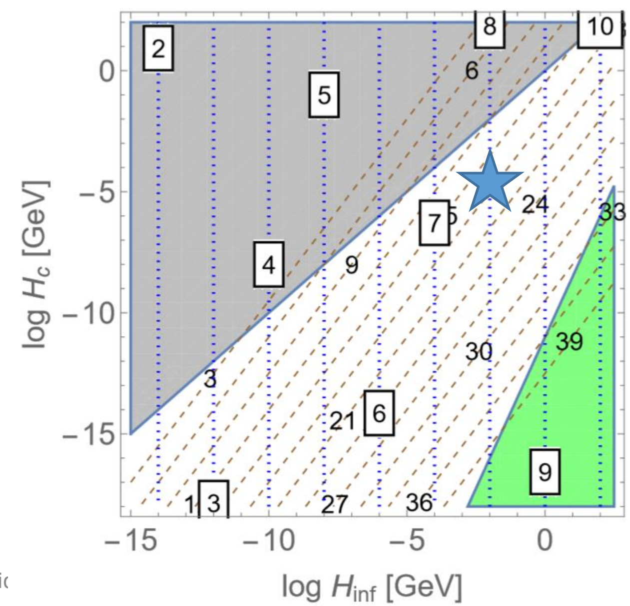
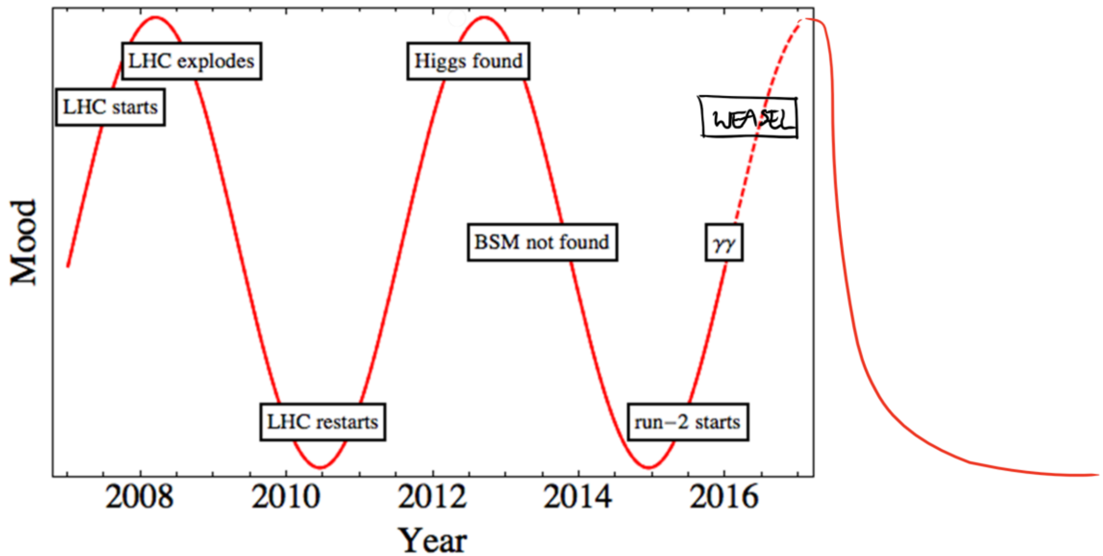
	M	g	H_I	H_c	N_e	Λ_G	f_ϕ	f_D/α_D
$\sim$ [GeV]	10^8	10^{-11}	10^{-2}	10^{-5}	10^{18}	$10^{3.5}$	10^9	10^{15}



Conclusion

http://resonaances.blogspot.com.es/2016/01/do-or-die-year.html



- Perhaps we are missing something in the way we think about the hierarchy problem?
- Models of natural weak scale with high cut-off are interesting to explore, realistic or not
- Motivates searching for alternative ways Higgs vev backreaction could dynamically select weak scale