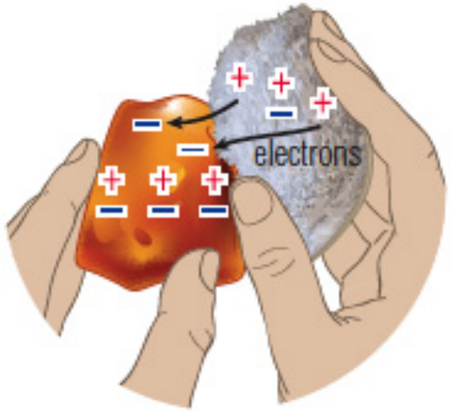
Scalars remember the hot big bang

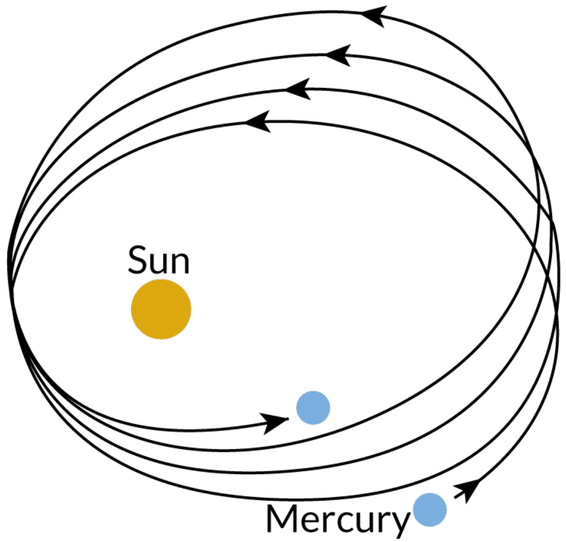
Minimal targets for dilaton direct detection [2408.XXXXX]

David Cyncynates (University of Washington), based on [2408.XXXXX] with Olivier Simon (Princeton)

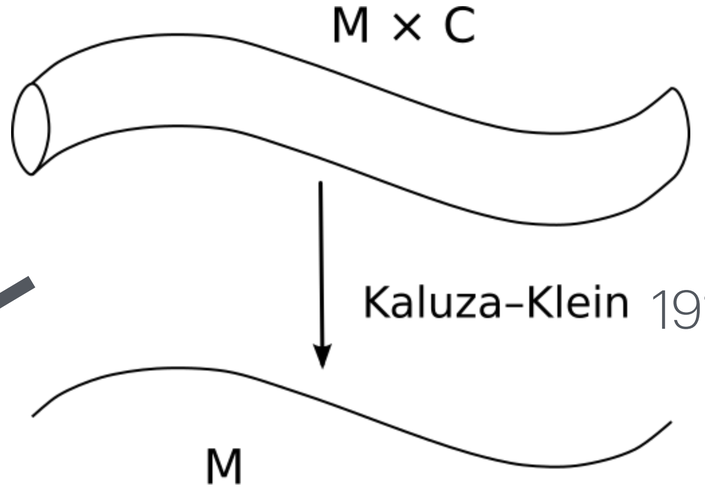
New forces



600 BC

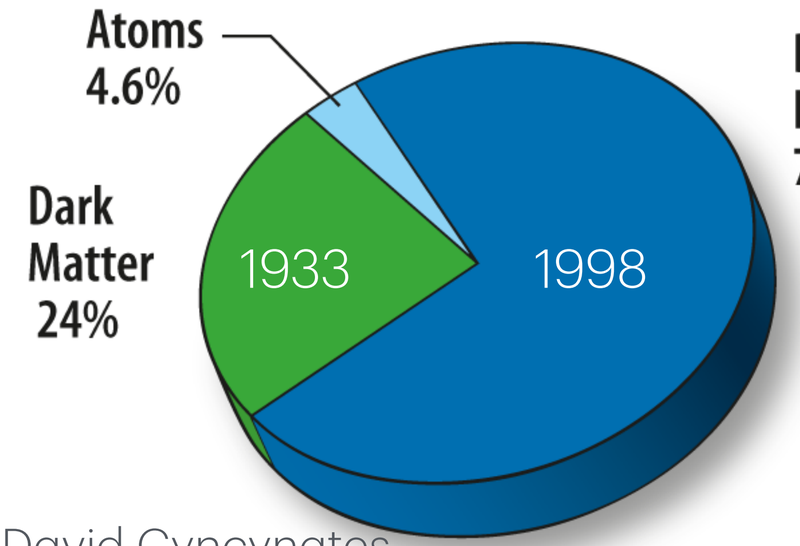


1859



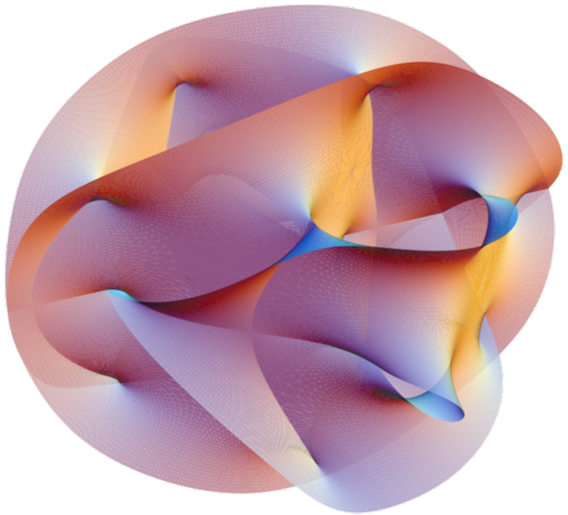
1919

New forces

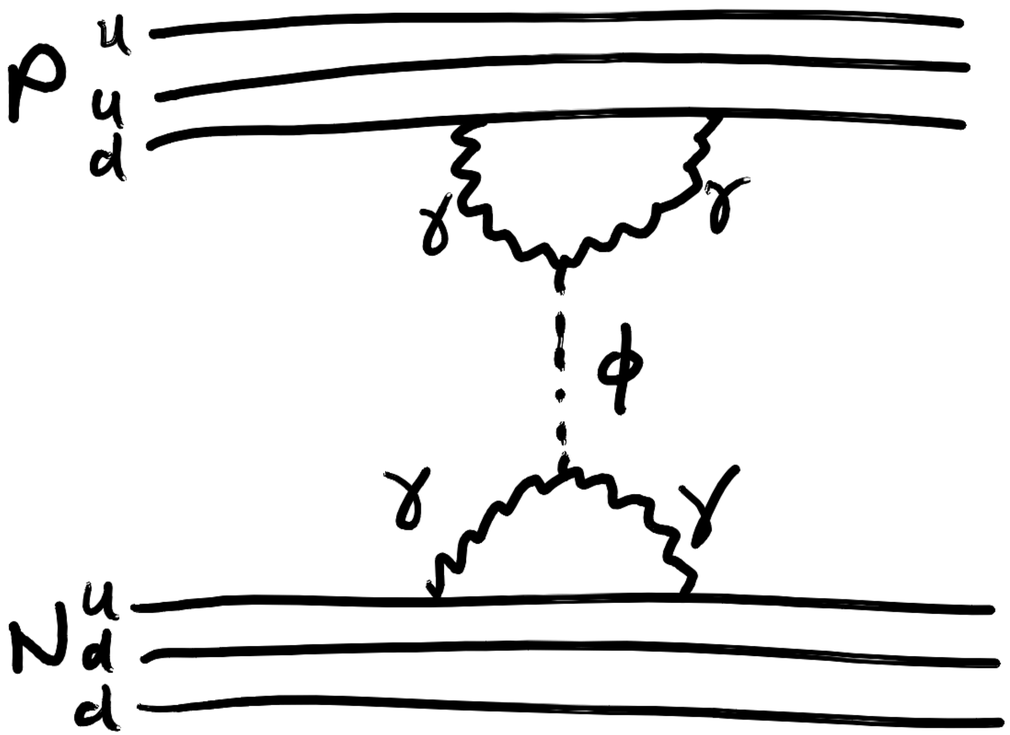


Dark Energy 71.4%

1990



Scalar mediated fifth forces

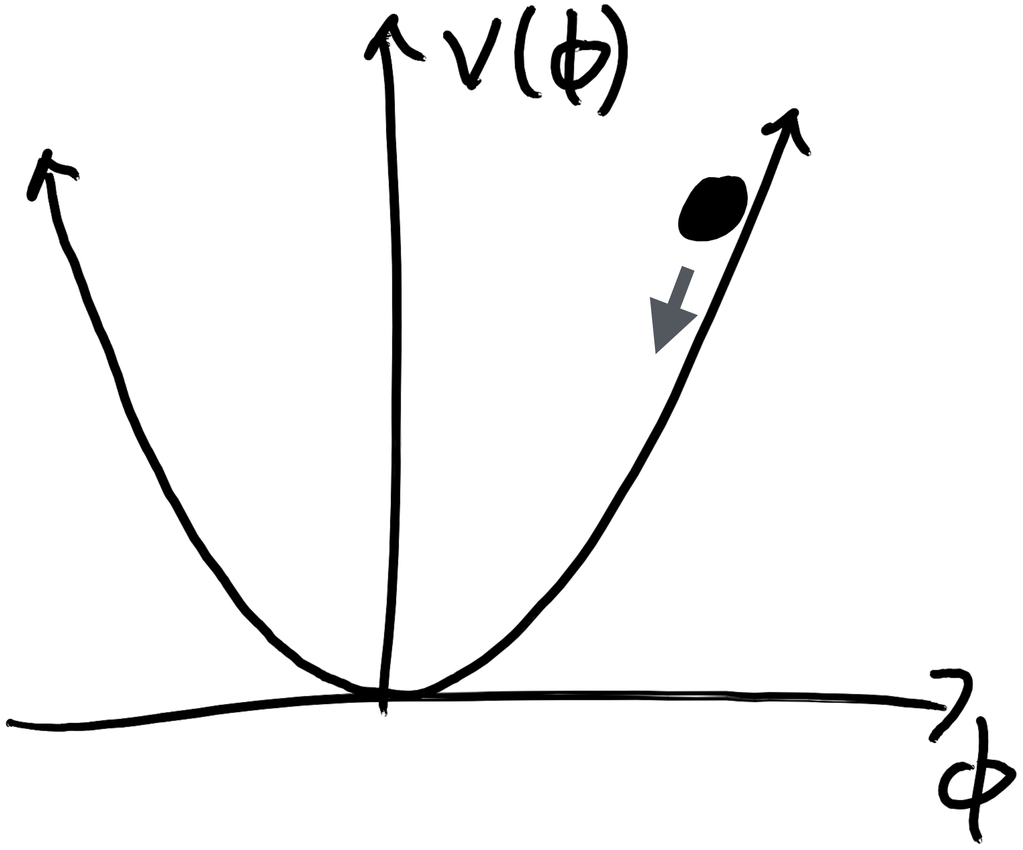


$$\Longrightarrow \quad V = -\frac{\alpha_5}{r} e^{-r m_\phi}$$

$$\frac{d_e \phi}{4 e^2 M_{\mathrm{pl}}} F_{\mu\nu} F^{\mu\nu}$$

Cosmological Consequences

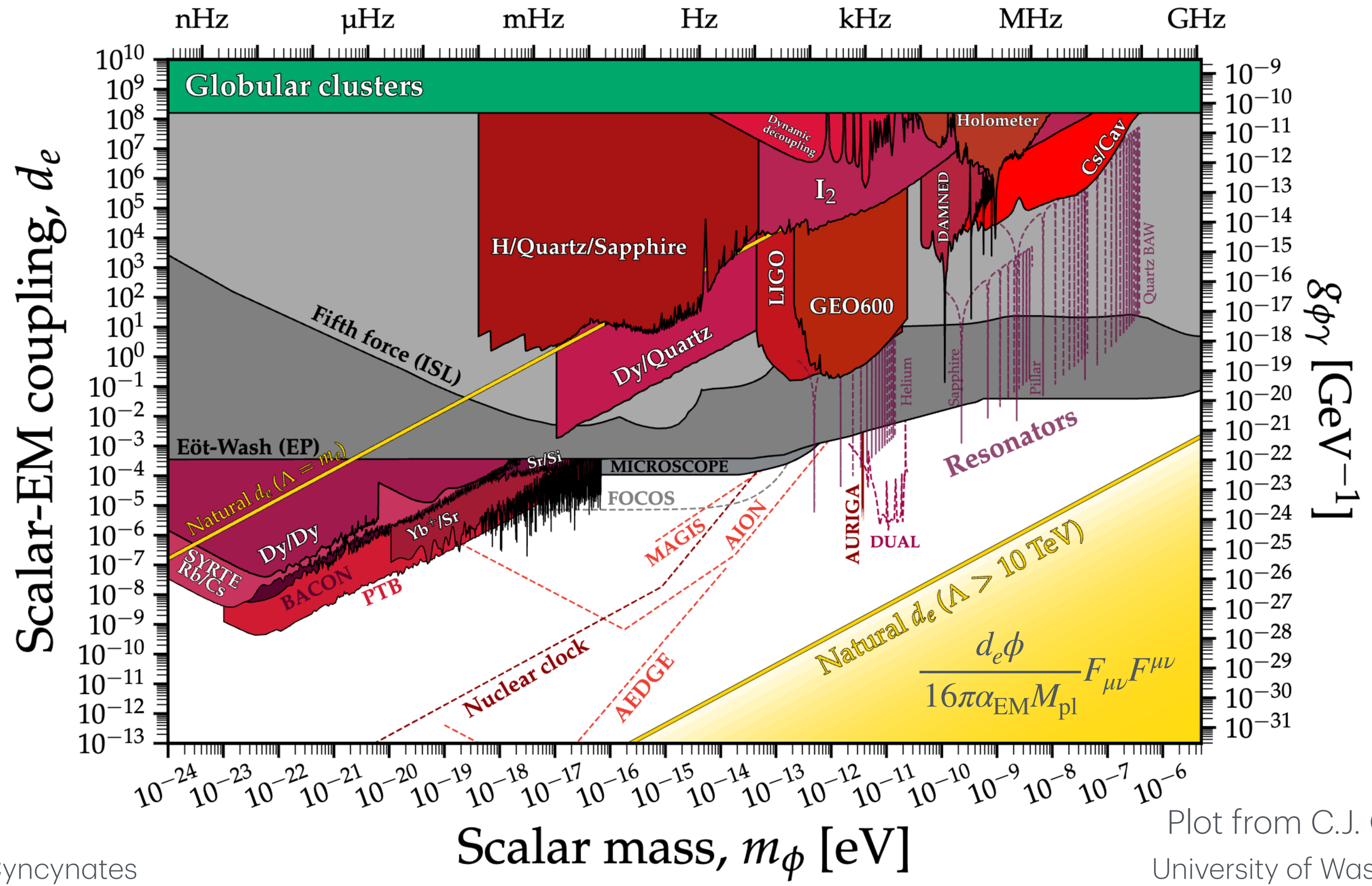
Misalignment production of dark matter



$$\ddot{\phi} + 3H\dot{\phi} + m_\phi^2 \phi = 0$$

$$\Omega_\phi \sim \left(\frac{m_\phi}{H_{\rm eq}}\right)^{1/2} \left(\frac{\phi_i}{M_{\rm pl}}\right)^2$$

$$\frac{d_e \phi}{4e^2 M_{\rm pl}} F_{\mu\nu} F^{\mu\nu} \Longrightarrow$$ Oscillating fundamental constants $\alpha_{\rm EM}(\phi)$



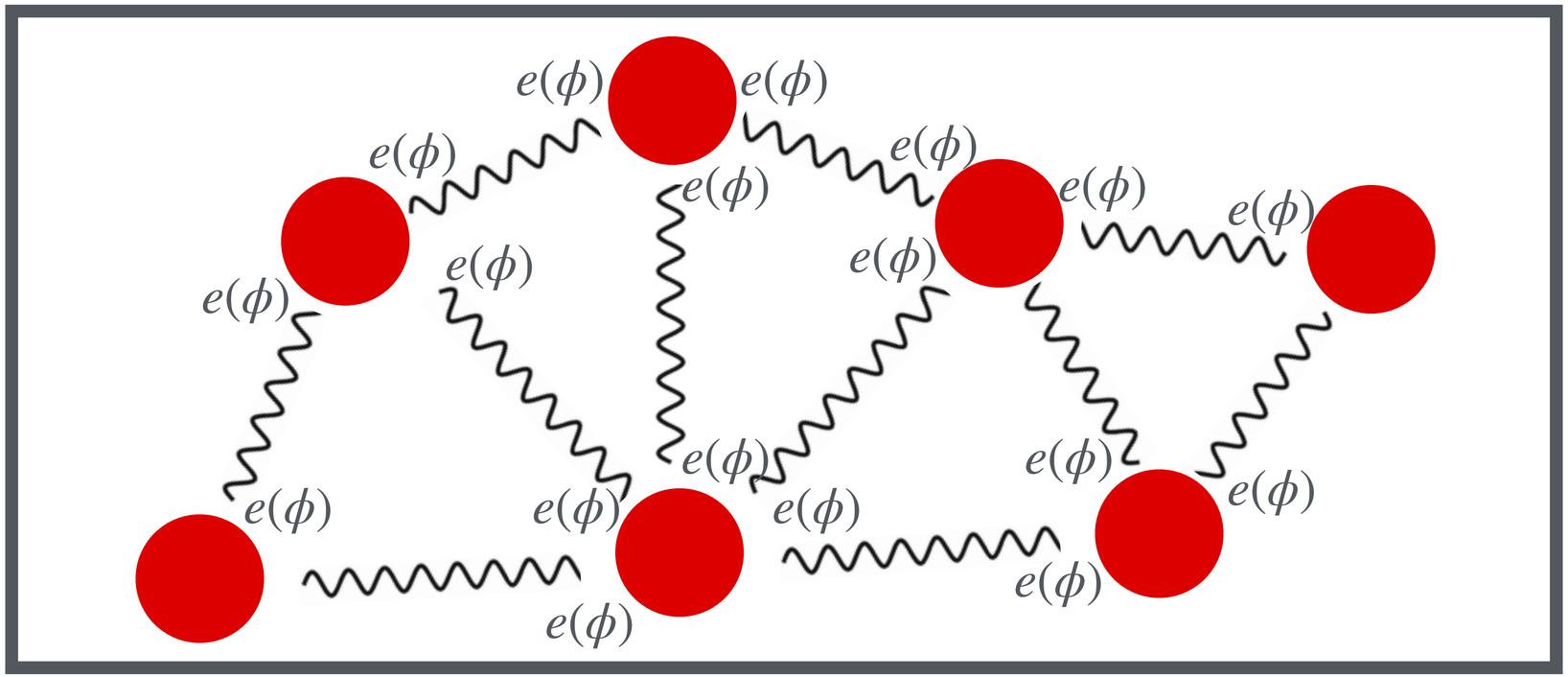
Plot from C.J. O'Hare

The thermal effective potential

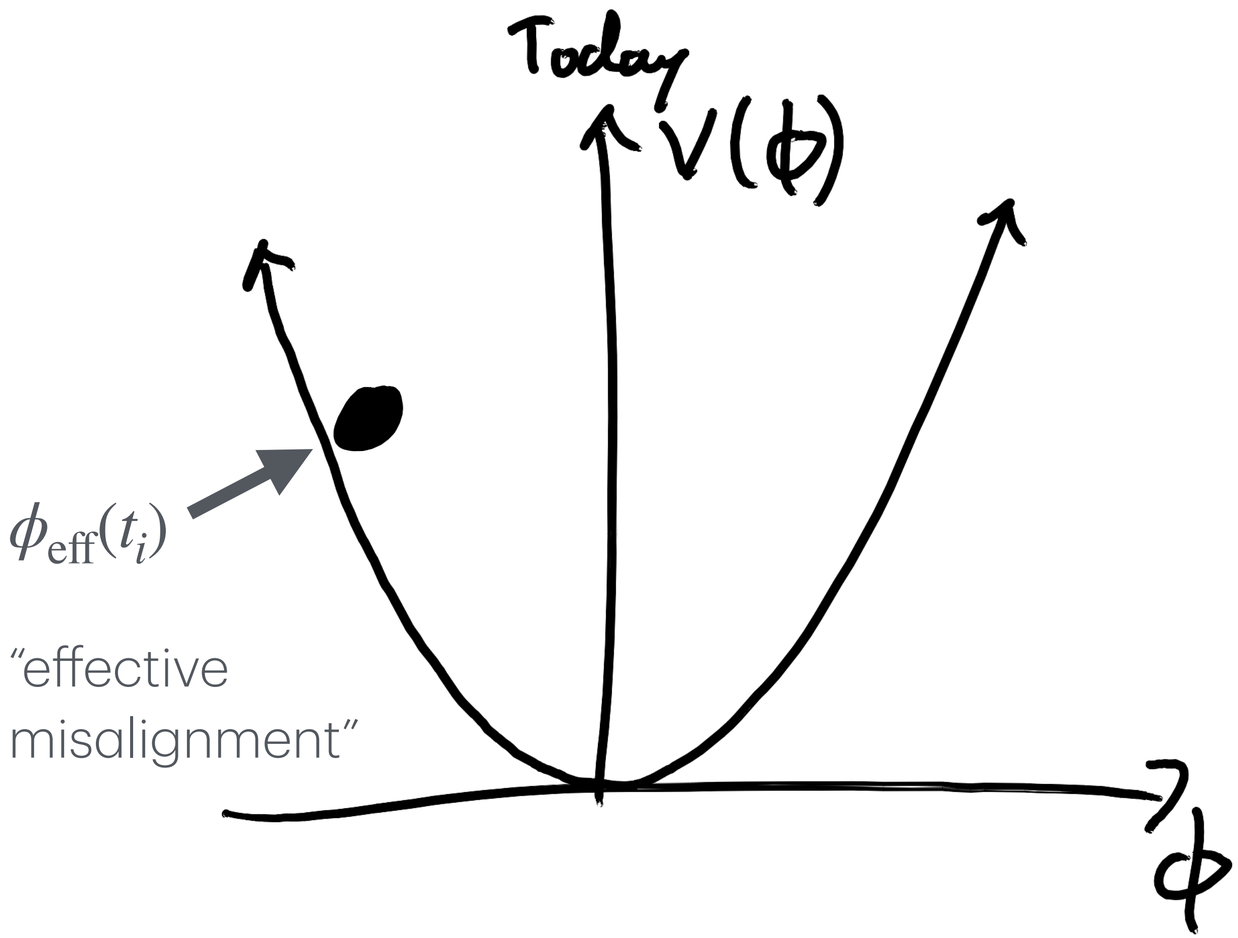
For a homogeneous system: $V_{\text{eff}}(\phi) = -\frac{T}{V}\log Z(\phi) = -P(\phi)$

Pressure is a measure of the force per area (time averaged) imparted to the barrier of a container

$$P \sim T^4\left(\frac{\pi^2}{45} - \frac{5}{288}e^2(\phi) + \ldots\right)$$

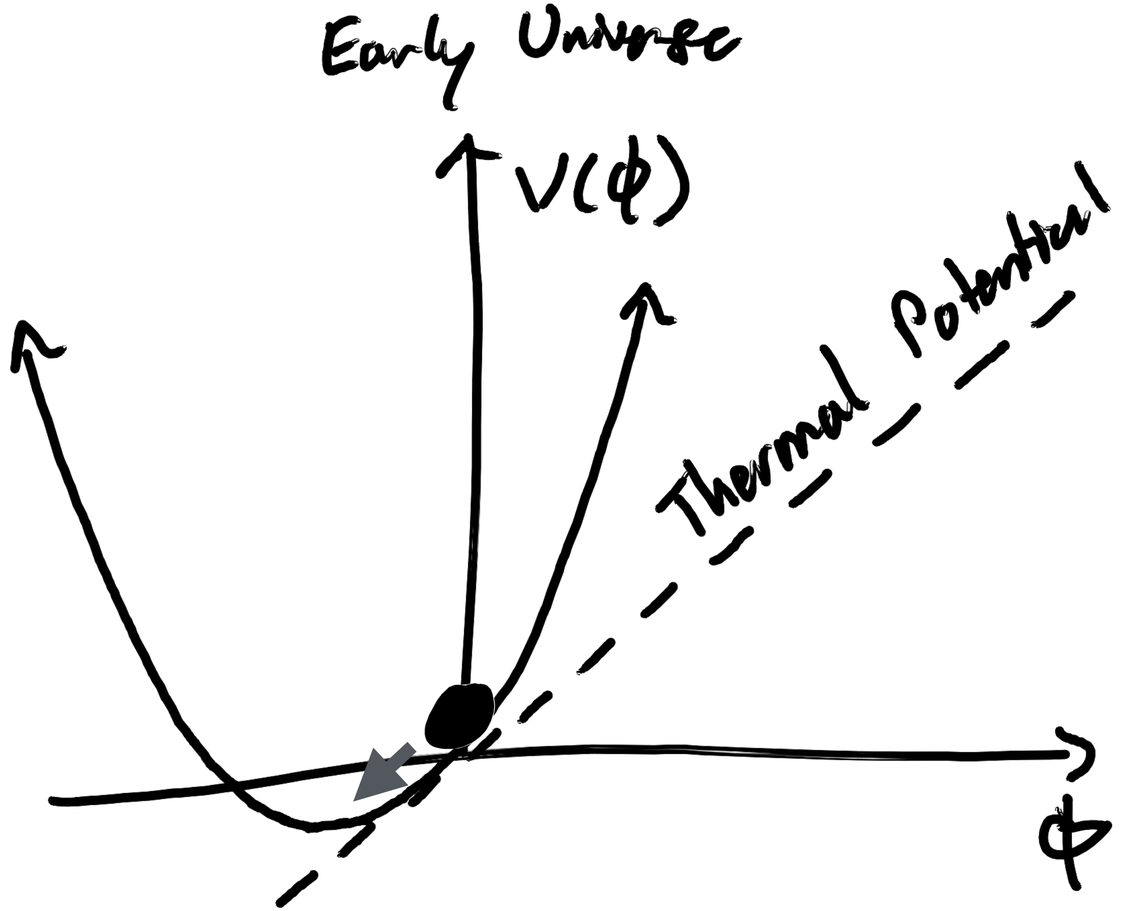


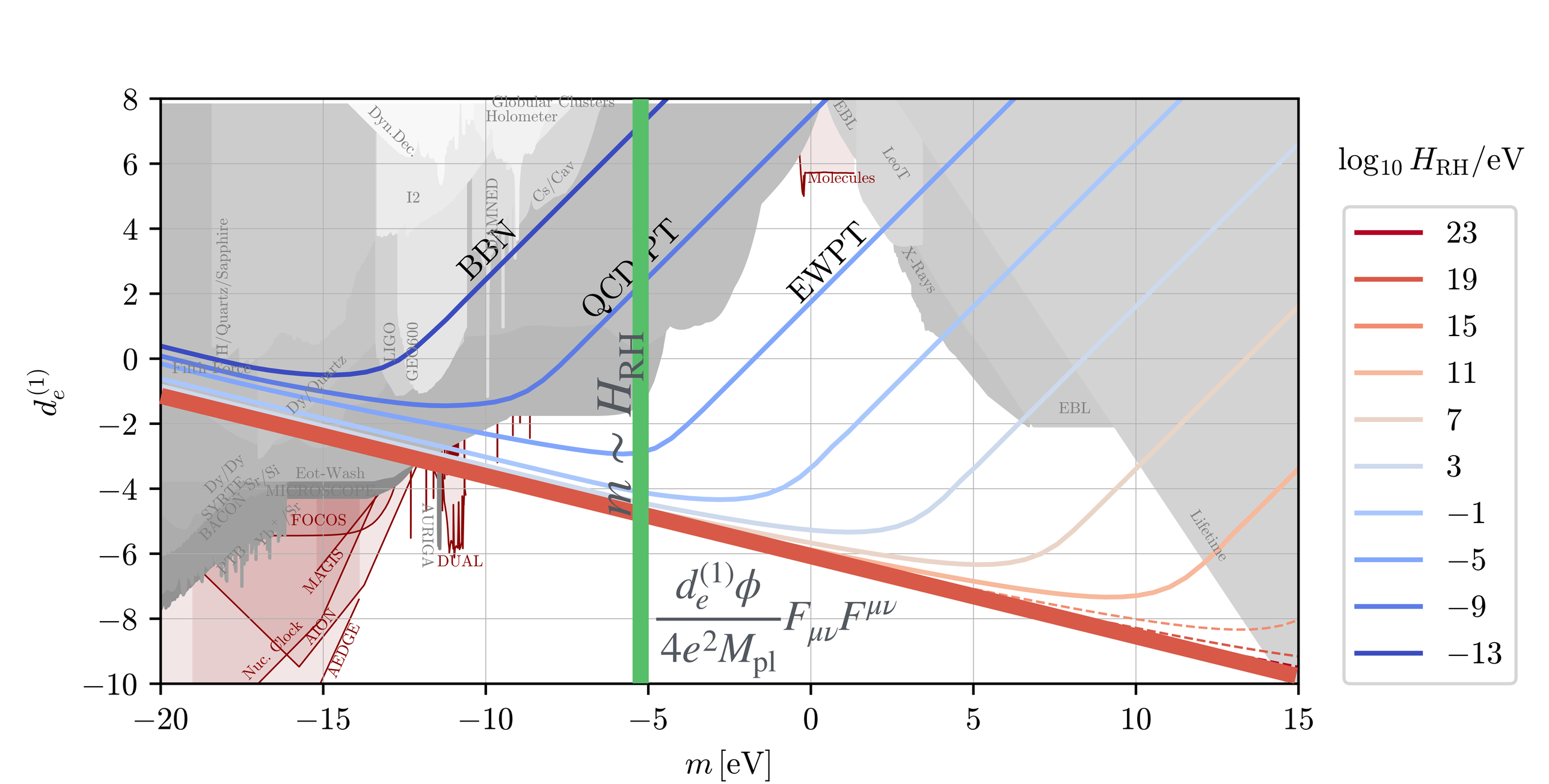
Scalar-Plasma Interactions



$\phi_{\text{eff}}(t_i)$

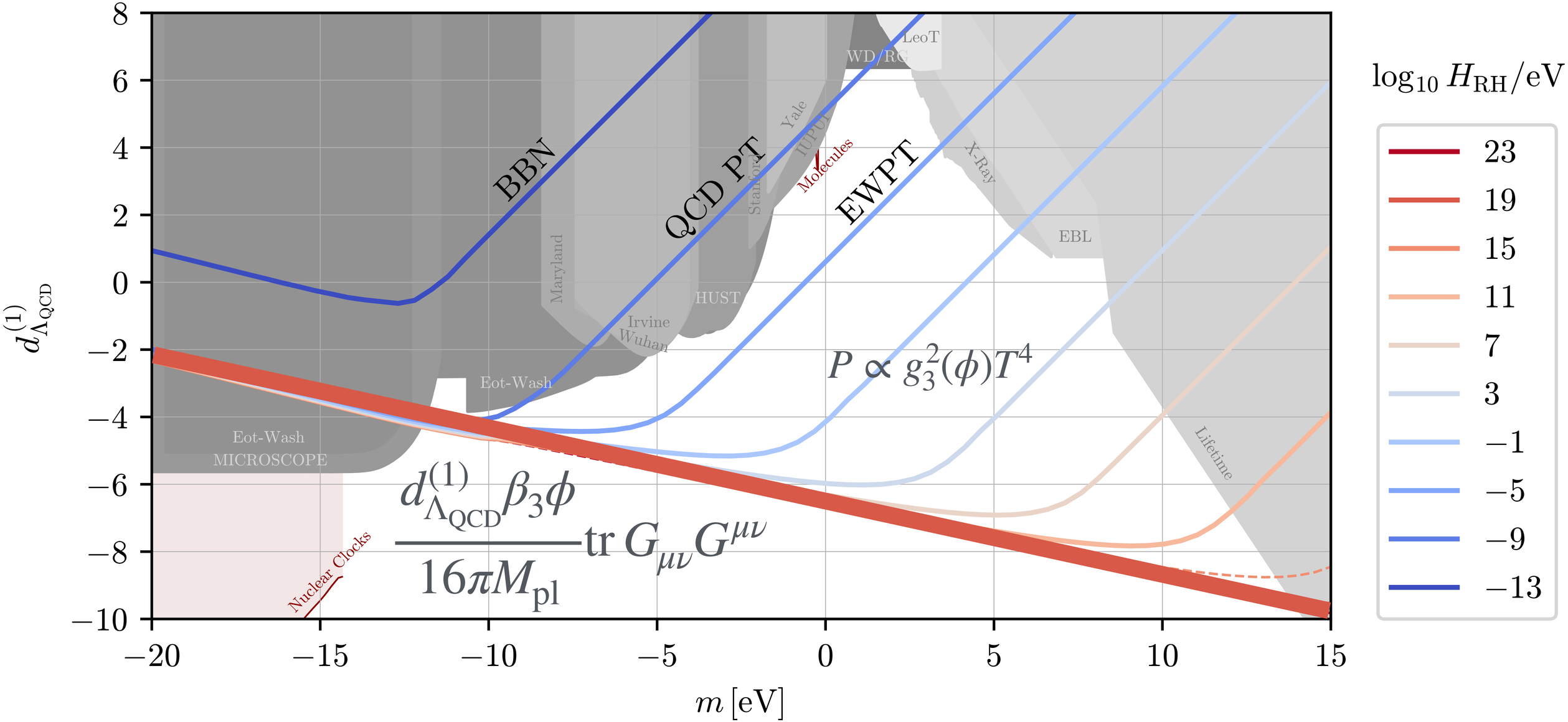
"effective misalignment"




$d_e^{(1)}$
m [eV]
$\log_{10} H_{\rm RH}/{\rm eV}$
23
19
15
11
7
3
−1
−5
−9
−13
BBN
QCDPT
EWPT
$m \sim H_{\rm RH}$
$\frac{d_e^{(1)}\phi}{4e^2 M_{\rm pl}} F_{\mu\nu}F^{\mu\nu}$
Globular Clusters
Holometer
Dyn.Dec.
I2
Cs/Cav
MNED
EBL
LeoT
Molecules
X-Rays
EBL
Lifetime
H/Quartz/Sapphire
LIGO
GEO600
Fifth Force
Dy/Quartz
Dy/Dy
SYRTE Sr/Si
BACON
Eot-Wash
MICROSCOPE
PTB Yb+/Sr
FOCOS
MAGIS
AURIGA
DUAL
Nuc. Clock
AION
AEDGE

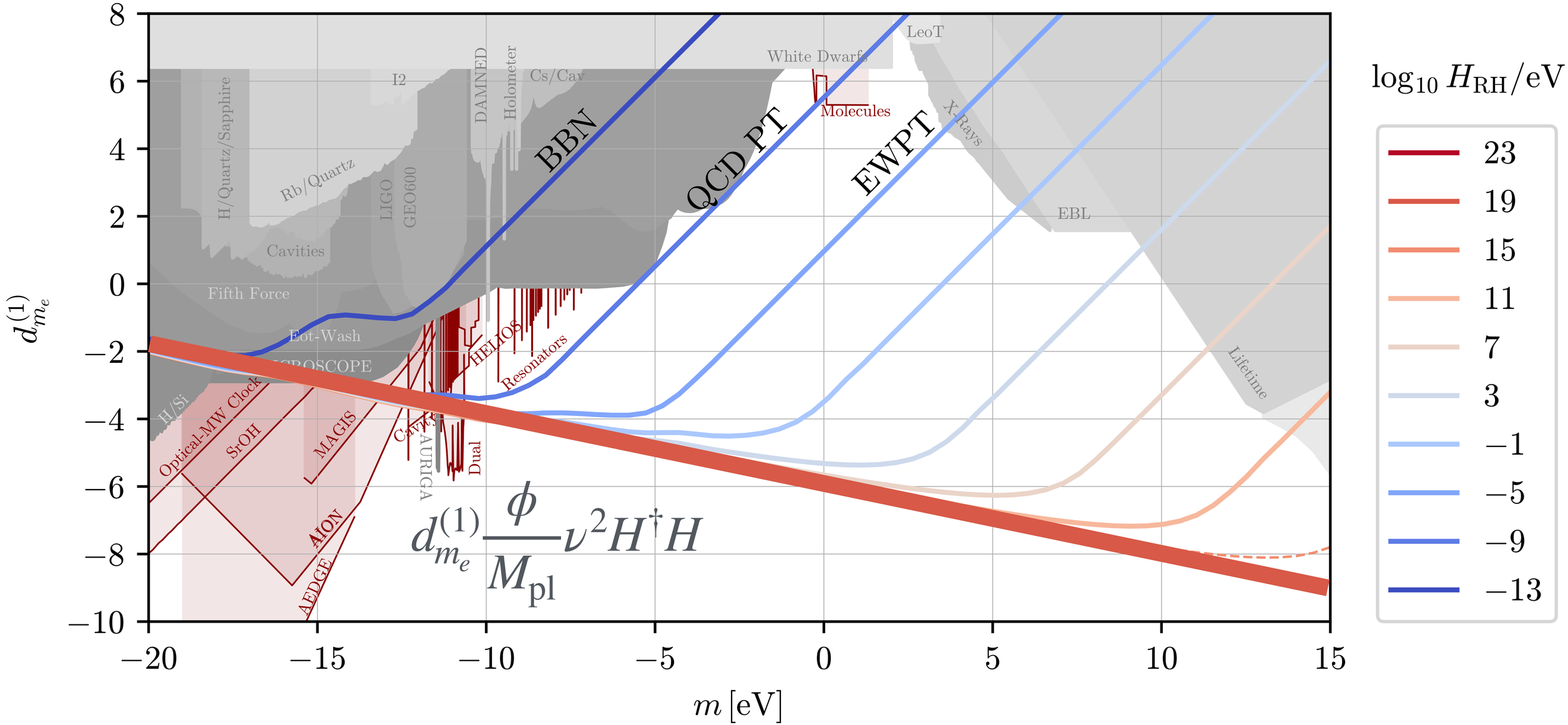
Couplings to particle masses?

Dimensional transmutation



Masses of fundamental particles?

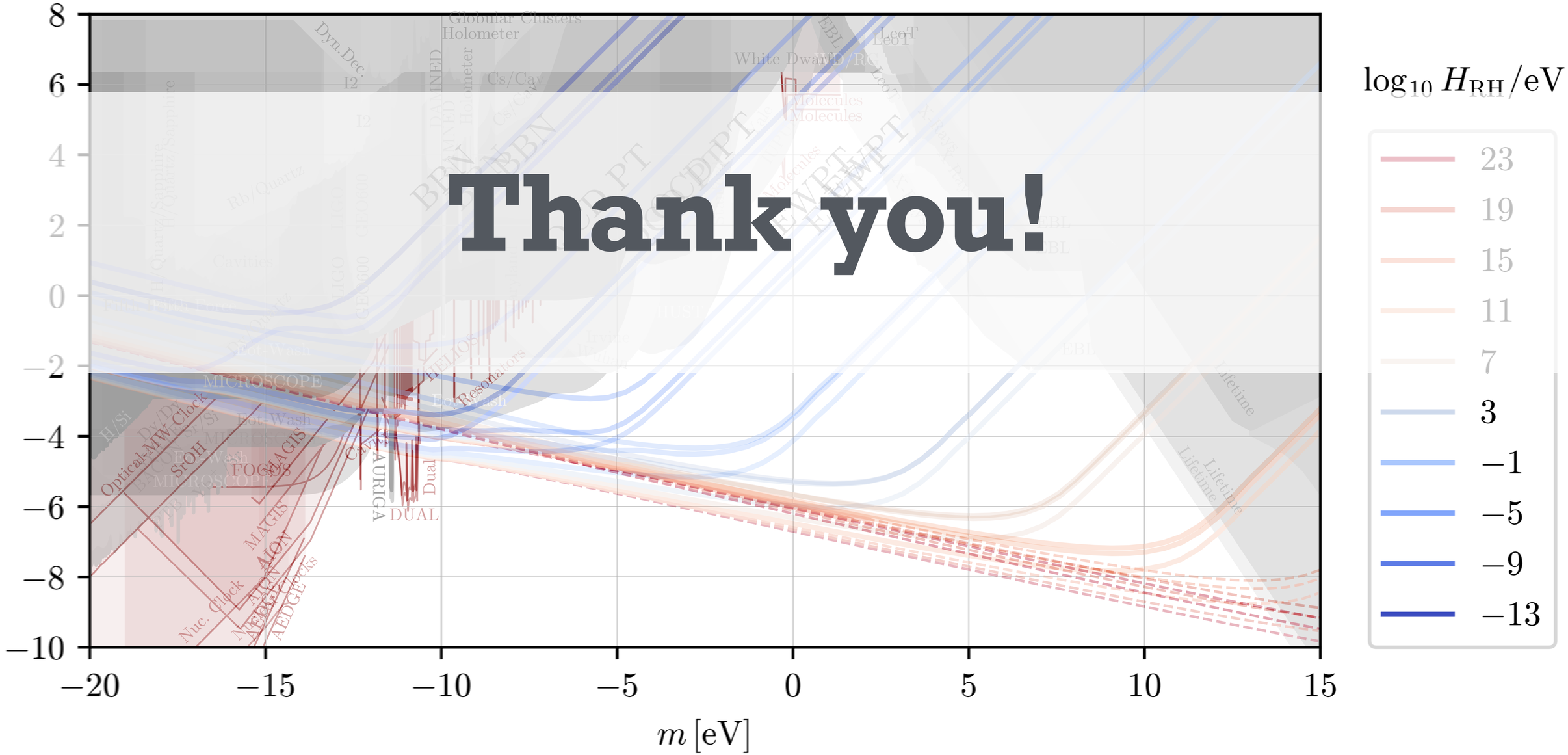
Running of the gauge couplings

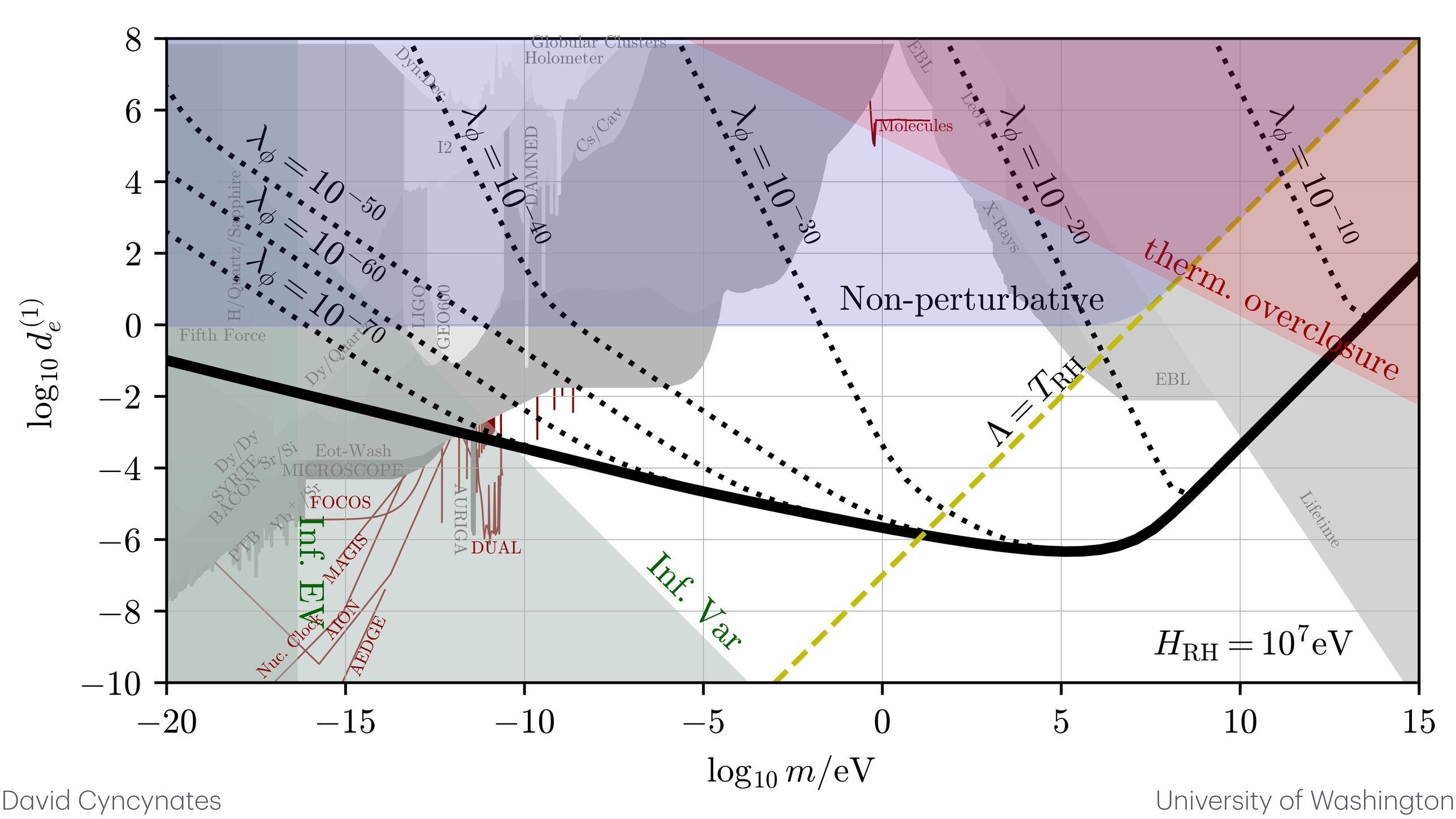


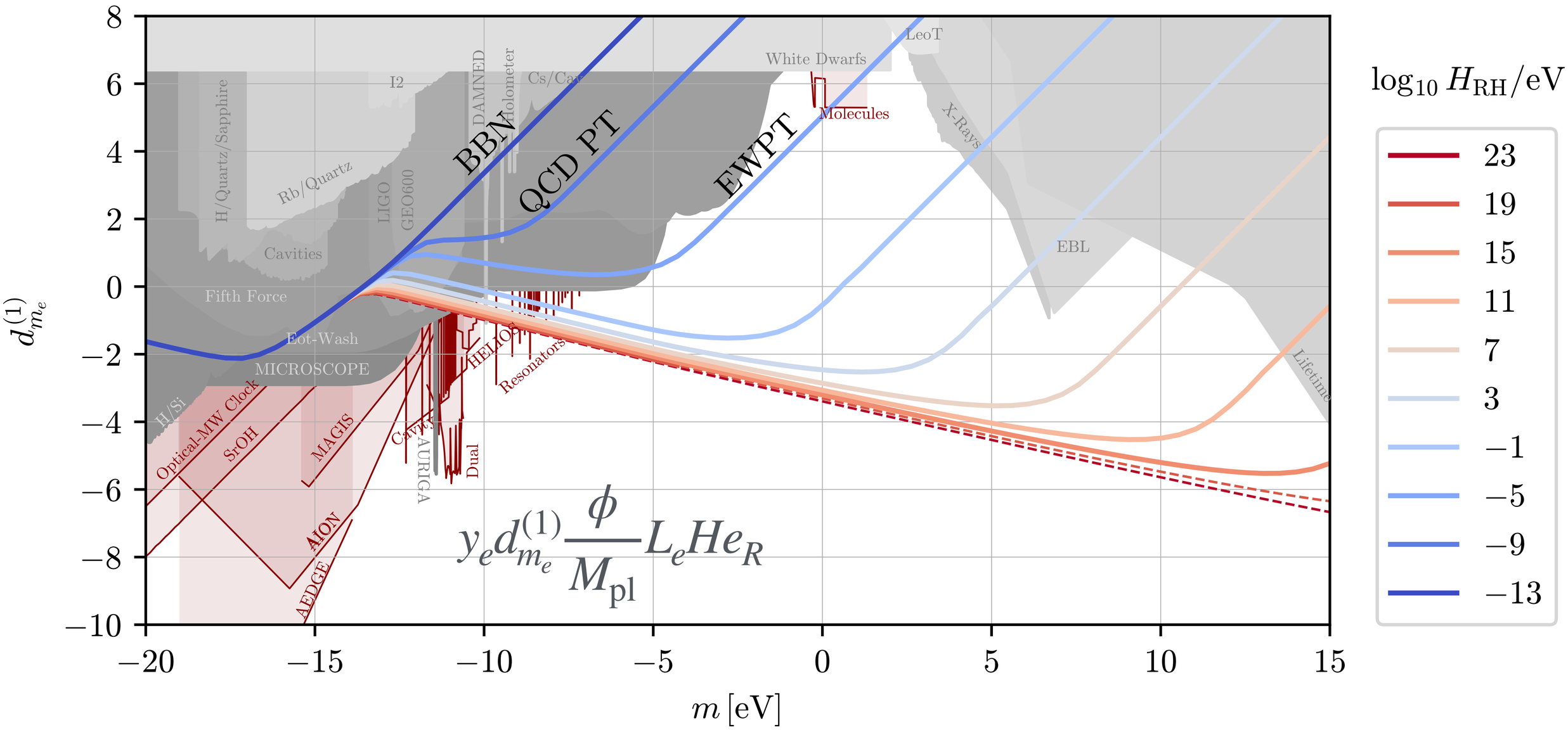
Conclusion

- Interactions mediated by scalar fields at lab energies make cosmological predictions
- Scalar couplings mix:
  - running of the gauge couplings
  - dimensional transmutation
  - spontaneous symmetry breaking
- Correct DM abundance for couplings larger than $d_X^{(1)} \sim 10^{-6}(m_\phi/\mathrm{eV})^{-1/4}$ relative to gravity
  - Firm observational target for future experiments

Minimal targets for dilaton direct detection [2408.XXXXX]




Globular Clusters
Holometer
DynDef.
I2
DAMNED
Cs/Cav
Molecules
EBL
Tests
X-Rays
$\lambda_\phi = 10^{-50}$
$\lambda_\phi = 10^{-60}$
$\lambda_\phi = 10^{-70}$
$\lambda_\phi = 10^{-40}$
$\lambda_\phi = 10^{-30}$
$\lambda_\phi = 10^{-20}$
$\lambda_\phi = 10^{-10}$
H/Quartz/Sapphire
Fifth Force
Dy/Quartz
LIGO
GEO600
Non-perturbative
therm. overclosure
$\Lambda = T_{\rm RH}$
EBL
Dy/Dy
SYRTE
BACON
Sr/Si
Eot-Wash
MICROSCOPE
Yb + Sr
PTB
FOCOS
MAGIS
AION
AEDGE
Nuc. Clock
Inf. EV
AURIGA
DUAL
Inf. Var
Lifetime
$H_{\rm RH} = 10^7 {\rm eV}$
$\log_{10} d_e^{(1)}$
$\log_{10} m/{\rm eV}$
8
6
4
2
0
−2
−4
−6
−8
−10
−20
−15
−10
−5
0
5
10
15


BBN
QCD PT
EWPT
White Dwarfs
LeoT
Molecules
X-Rays
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Holometer
Cs/Cav
H/Quartz/Sapphire
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Cavities
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MICROSCOPE
H/Si
Optical-MW Clock
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MAGIS
AION
AEDGE
AURIGA
Cavity
Dual
HELIOS
Resonators
$y_e d^{(1)}_{m_e} \frac{\phi}{M_{\rm pl}} L_e He_R$
$d^{(1)}_{m_e}$
$m\,[\mathrm{eV}]$
$\log_{10} H_{\rm RH}/\mathrm{eV}$
23
19
15
11
7
3
−1
−5
−9
−13