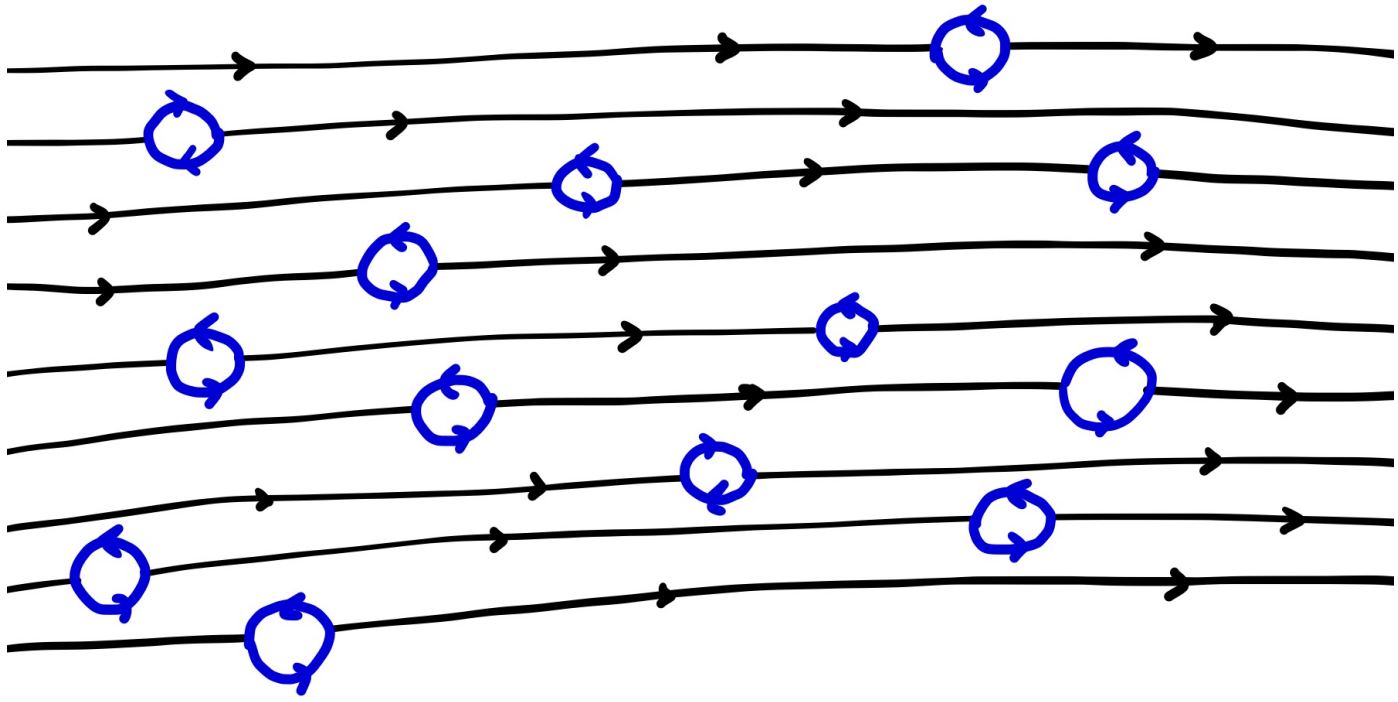
Inflationary Schwinger Dark Matter Production



Roberto Vega-Morales

UNIVERSIDAD DE GRANADA

DMLAND Workshop, MITP

Mainz Germany, September 4, 2024

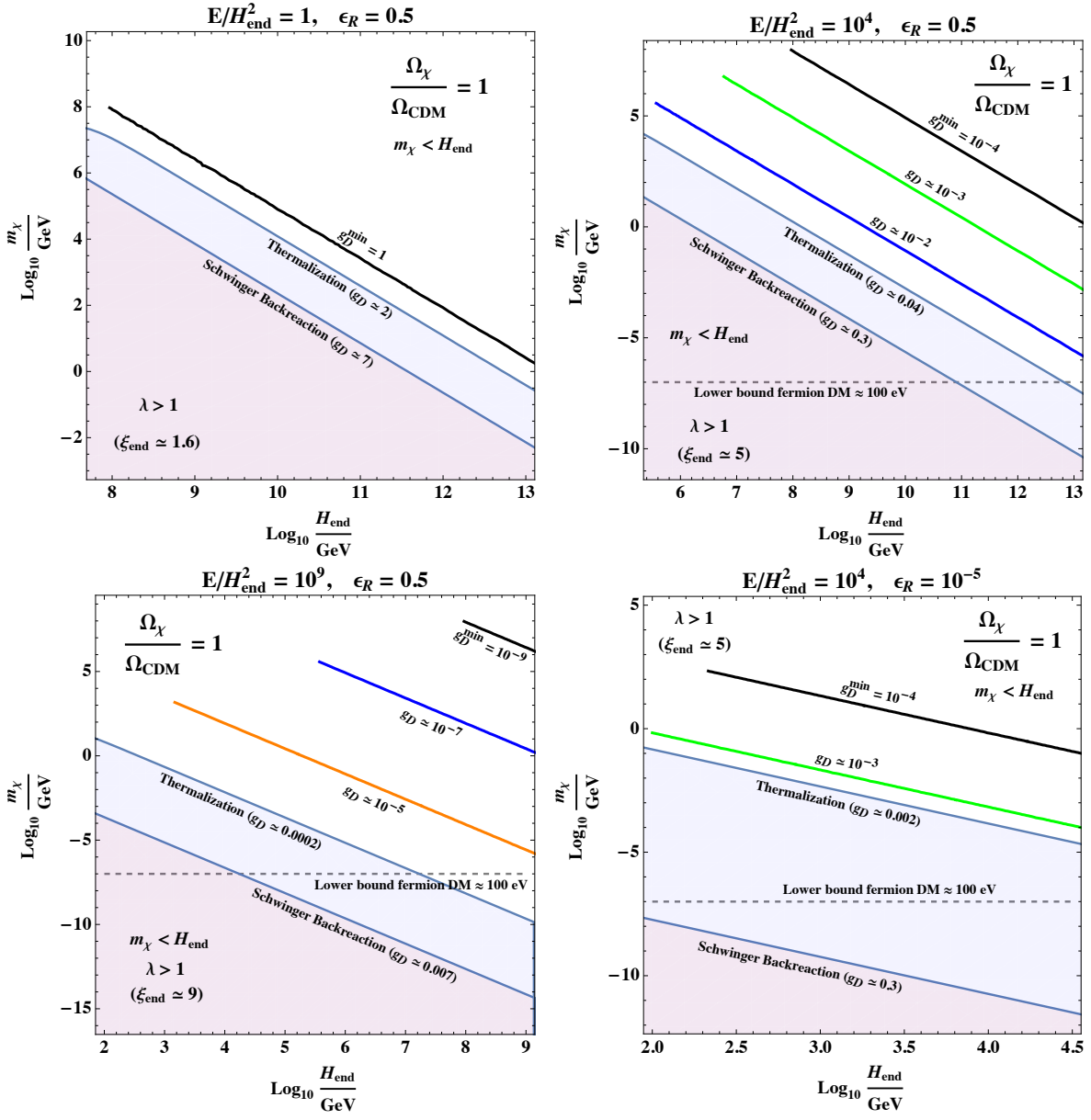
In collaboration with Mar Bastero-Gil, Paulo Ferraz, Jose Santiago, Lorenzo Ubaldi, RVM

(1810.07208, 2103.12145, 2311.09475, 2311.15137, + ongoing)

DM Parameter Space ($g_D E > H_{\rm end}^2, m_\chi < H_{\rm end}$)

Strong

Mar Bastero-Gil, Paulo B. Ferraz, Lorenzo Ubaldi, RVM: 2312.15137

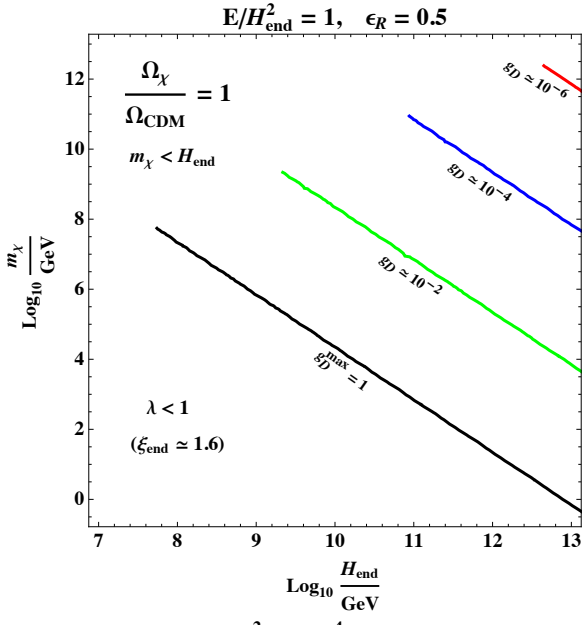


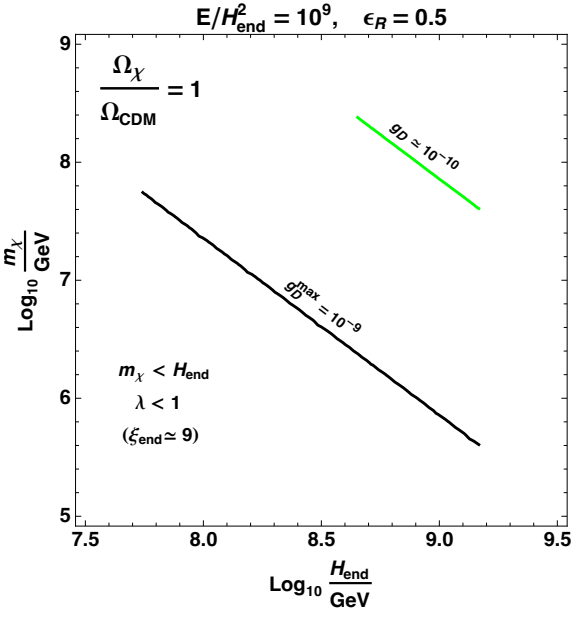
DM Parameter Space ($g_D E < H_{\rm end}^2, m_\chi < H_{\rm end}$)

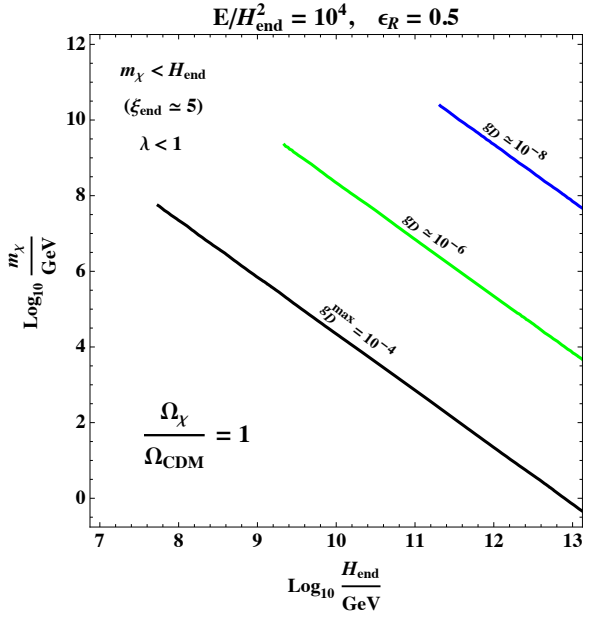
weak

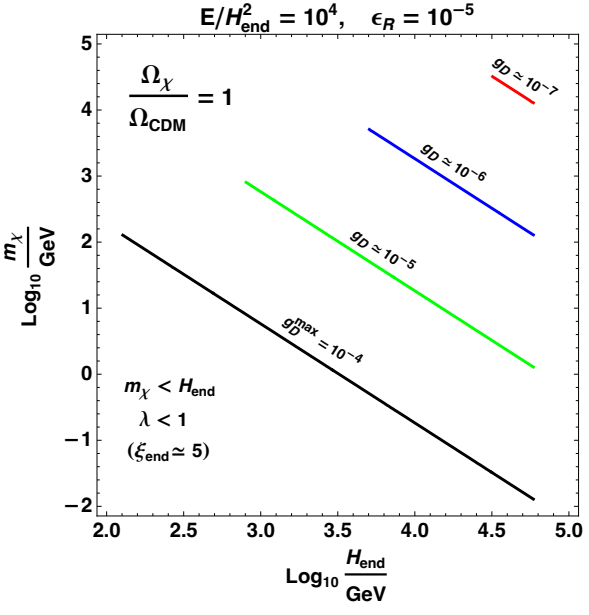
Mar Bastero-Gil, Paulo B. Ferraz, Lorenzo Ubaldi, RVM: 2312.15137

Note: Weak electric force regime NOT possible in flat space!



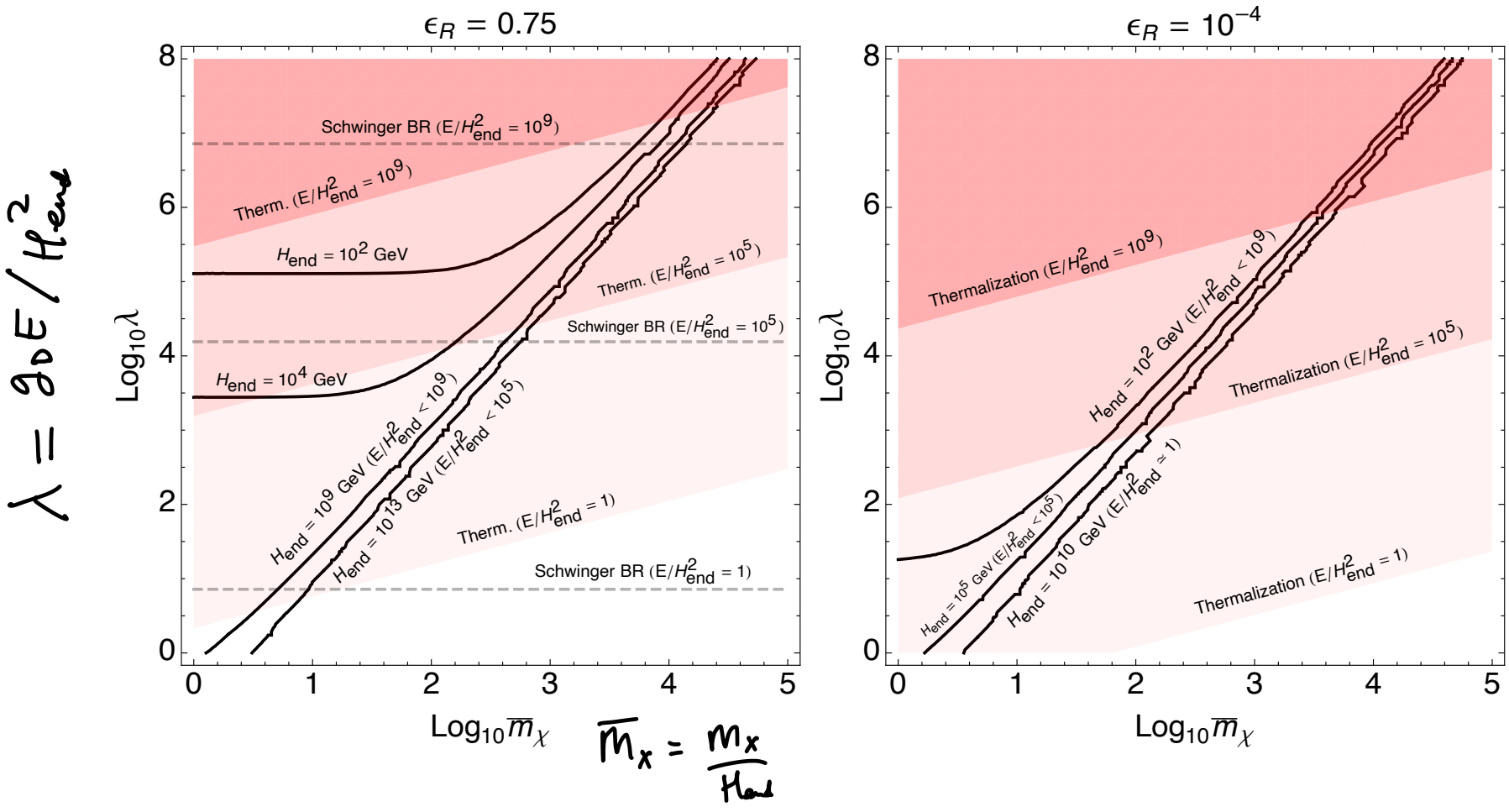






DM Parameter Space ($g_D E > H_{\rm end}^2, m_\chi > H_{\rm end}$)

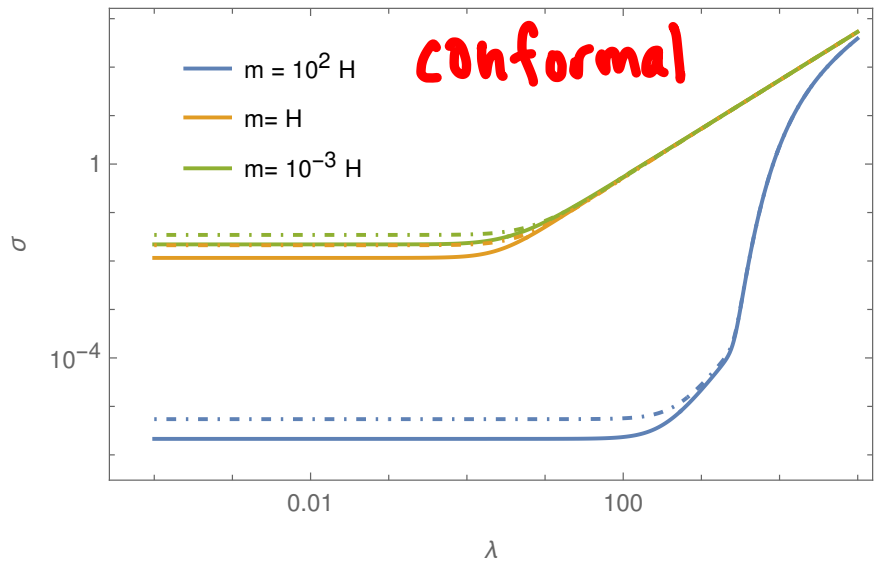
Mar Bastero-Gil, Paulo B. Ferraz, Lorenzo Ubaldi, RVM: 2311.09475

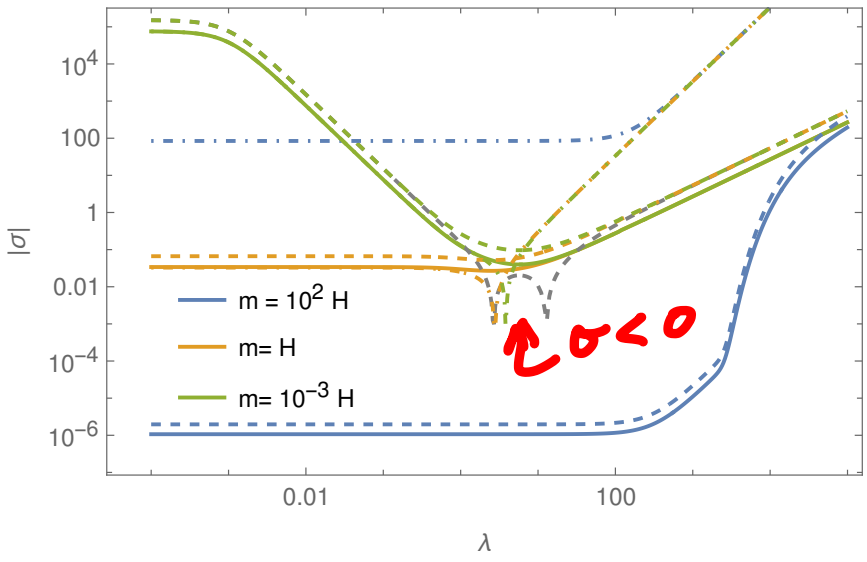


Can generate DM with mass $m_\chi \gg H_{\rm end}$ which would be exponentially suppressed in purely gravitational production

Schwinger Current in de-Sitter

M. Bastero-Gil, P. B. Ferraz, A. Torres Manso, L. Ubaldi, RVM: **PRELIMINARY**





We find strictly positive conductivities and in the conformal limit and similar results for both fermions and scalars

↳ contrary to literature!

(Kobayashi, et.al: 1408.4141 and Banyeres, et.al: 1809.08772)

Summary and Conclusions

- Have presented an inflationary Schwinger (non-thermal) dark matter production mechanism
- Can generate observed relic abundance for 'dark electron' masses in the range $0.1\,\mathrm{eV} \lesssim m_\chi \lesssim 10^{15}\,\mathrm{GeV}$ (lower limit of 100 eV for fermions)
- Viable even in the conformal limit (massless) when purely gravitational production is absent
- Also viable in the $m_\chi > H_{\mathrm{end}}$ regime where purely gravitational production is exponentially suppressed
- Examining current in de-Sitter space
- Examining backreaction and reheating effects

GRACIAS!

AND COME VISIT!

EXTRA SLIDES!

Constraints on Model Parameters

No-Thermalization within dark sector (or with SM)

$$g_D \lesssim 2 \left(\frac{\overline{m}_\chi \epsilon_R^2}{(E/H_{\rm end}^2)^3} \right)^{1/7}$$

No Schwinger backreaction

$$\overline{\sigma} < 1$$

No backreaction on inflaton dynamics

$$\rho_E^{\rm end} < \rho_I^{\rm end} \Rightarrow 1 < \frac{E}{H_{\rm end}^2} < 10^9$$

Visible sector must have more energy density than dark sector at end of reheating (to ensure matter radiation equality)

$$\rho_E^{\rm end} < \rho_R \Rightarrow H_{\rm end} < \frac{\sqrt{6}\,\epsilon_R^2 M_{\rm Pl}}{(E/H_{\rm end}^2)}$$

Producing a Dark Electric Field

To have a current need a (background) dark E-field

In principle any inflationary VDM mechanisms can work

Inspired by magnetogenesis in axion inflation models

$$\mathcal{L}_{\rm source}(A_\mu,\phi) \;=\; \frac{1}{2}\partial_\mu\phi\partial^\mu\phi + V(\phi) + \frac{\alpha}{4f}\phi F_{\mu\nu}\tilde{F}^{\mu\nu}$$

Can reproduce observed DM relic abundance for:
$\mu\mathrm{eV} \lesssim m_A \lesssim \mathrm{TeV}$, $100\ \mathrm{GeV} \lesssim H \lesssim 10^{14}\ \mathrm{GeV}$

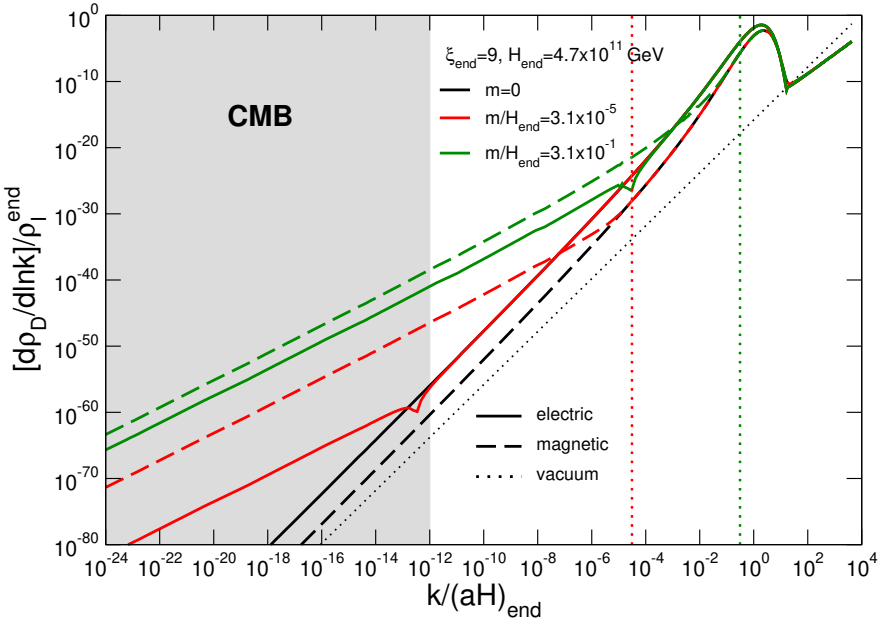
(Bastero-Gil, Santiago, Ubaldi, RVM: 1810.07208, 2103.12145)

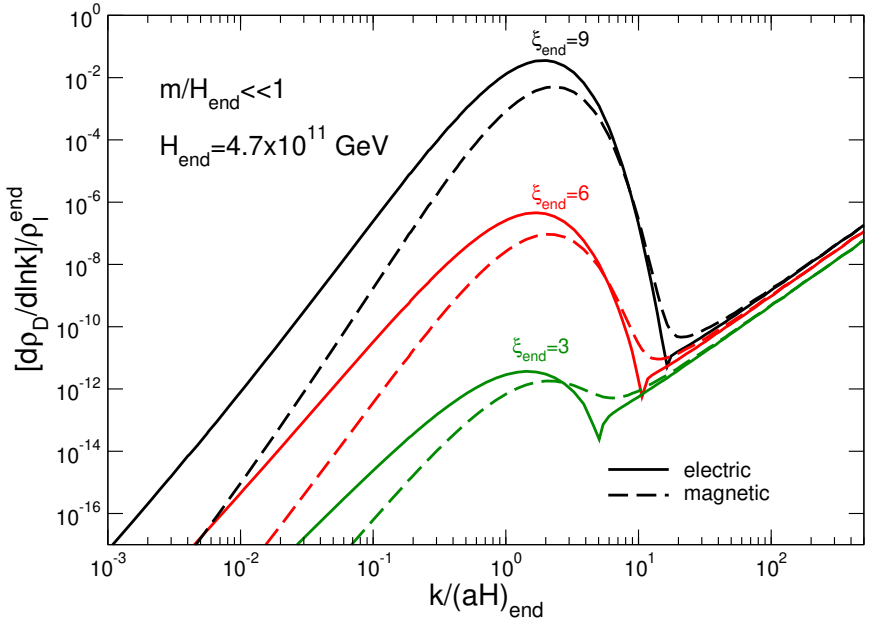
Dark E-field polarized with peak in energy density spectrum

Coherence length size of the horizon at end of inflation

Energy density spectrum at end of inflation

(Mar Bastero-Gil, Jose Santiago, Lorenzo Ubaldi, RVM: 1810.07208, 2103.12145)





Power spectrum is peaked at very small scales ($\sim cm - km$)

$\Rightarrow$ power suppressed at CMB scales evading isocurvature limits

Inflationary dark vector production mechanisms

A. E. Nelson and J. Scholtz, *Dark Light, Dark Matter and the Misalignment Mechanism*, *Phys. Rev.* **D84** (2011) 103501, [arXiv:1105.2812].

P. Arias, D. Cadamuro, M. Goodsell, J. Jaeckel, J. Redondo, and A. Ringwald, *Wispy Cold Dark Matter*, *JCAP* **1206** (2012) 013, [arXiv:1201.5902].

P. W. Graham, J. Mardon, and S. Rajendran, *Vector Dark Matter from Inflationary Fluctuations*, *Phys. Rev.* **D93** (2016), no. 10 103520, [arXiv:1504.02102].

M. Bastero-Gil, J. Santiago, L. Ubaldi, and R. Vega-Morales, *Vector dark matter production at the end of inflation*, *JCAP* **1904** (2019), no. 04 015, [arXiv:1810.07208].

Y. Ema, K. Nakayama, and Y. Tang, *Production of Purely Gravitational Dark Matter: The Case of Fermion and Vector Boson*, *JHEP* **07** (2019) 060, [arXiv:1903.10973].

K. Nakayama, *Constraint on Vector Coherent Oscillation Dark Matter with Kinetic Function*, *JCAP* **08** (2020) 033, [arXiv:2004.10036].

Y. Nakai, R. Namba, and Z. Wang, *Light Dark Photon Dark Matter from Inflation*, *JHEP* **12** (2020) 170, [arXiv:2004.10743].

A. Ahmed, B. Grzadkowski, and A. Socha, *Gravitational production of vector dark matter*, *JHEP* **08** (2020) 059, [arXiv:2005.01766].

E. W. Kolb and A. J. Long, *Completely Dark Photons from Gravitational Particle Production During Inflation*, arXiv:2009.03828.

B. Salehian, M. A. Gorji, H. Firouzjahi, and S. Mukohyama, *Vector dark matter production from inflation with symmetry breaking*, arXiv:2010.04491.

H. Firouzjahi, M. A. Gorji, S. Mukohyama, and B. Salehian, *Dark photon dark matter from charged inflaton*, arXiv:2011.06324.