Cosmology From Home

5-16 July 2021

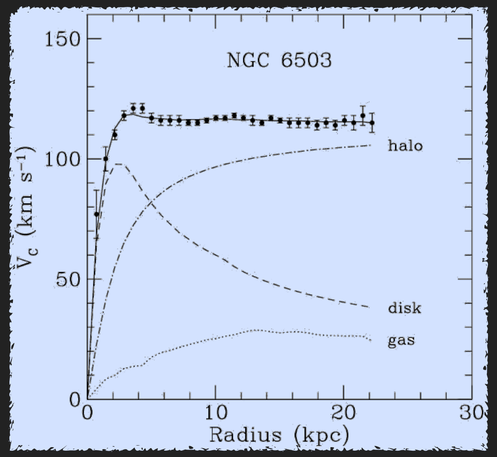
DAVIDE RACCO

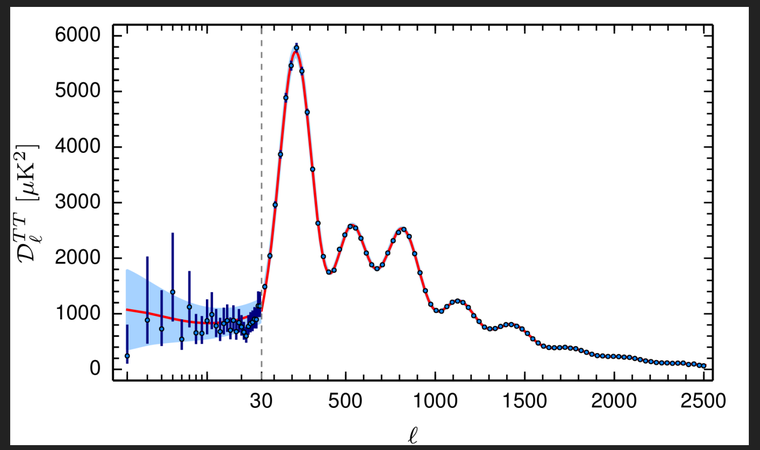
PERIMETER INSTITUTE

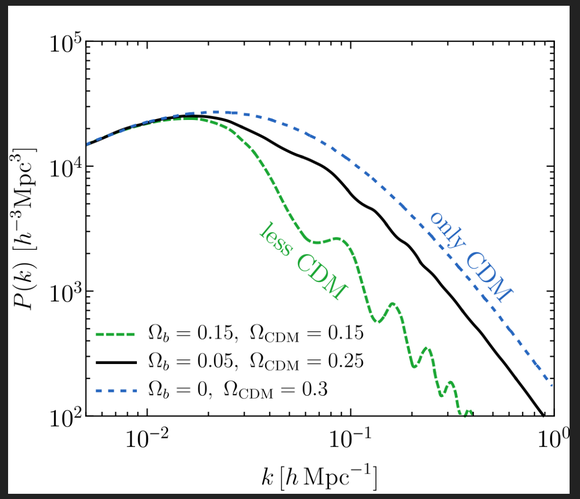
Gravitational Production of Dark Sectors

arχiv: 2107.? with Asimina Arvanitaki, Savas Dimopoulos,
Marios Galanis, Olivier Simon, Jed Thompson

GRAVITATIONAL EVIDENCES FOR DARK MATTER

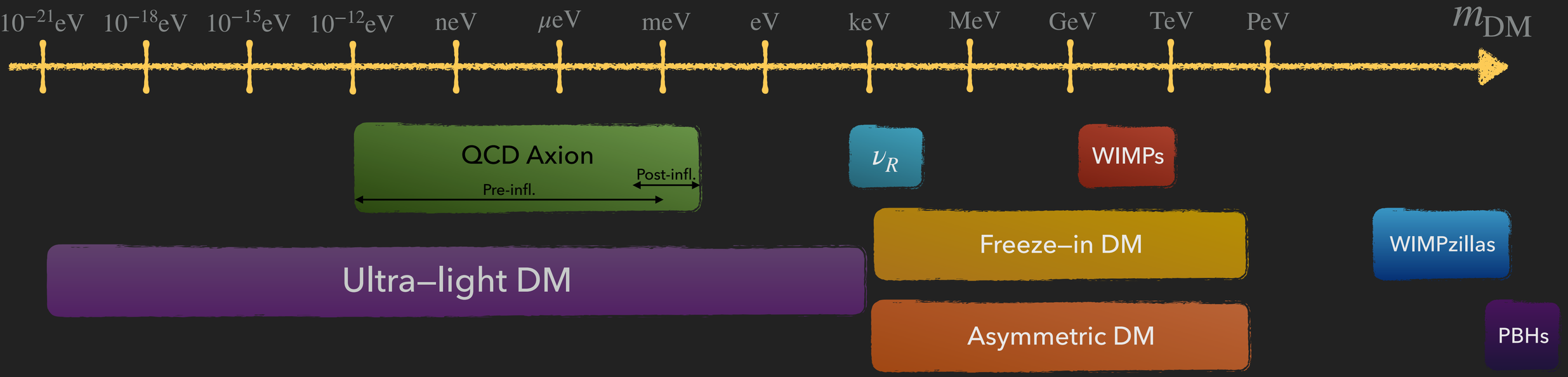






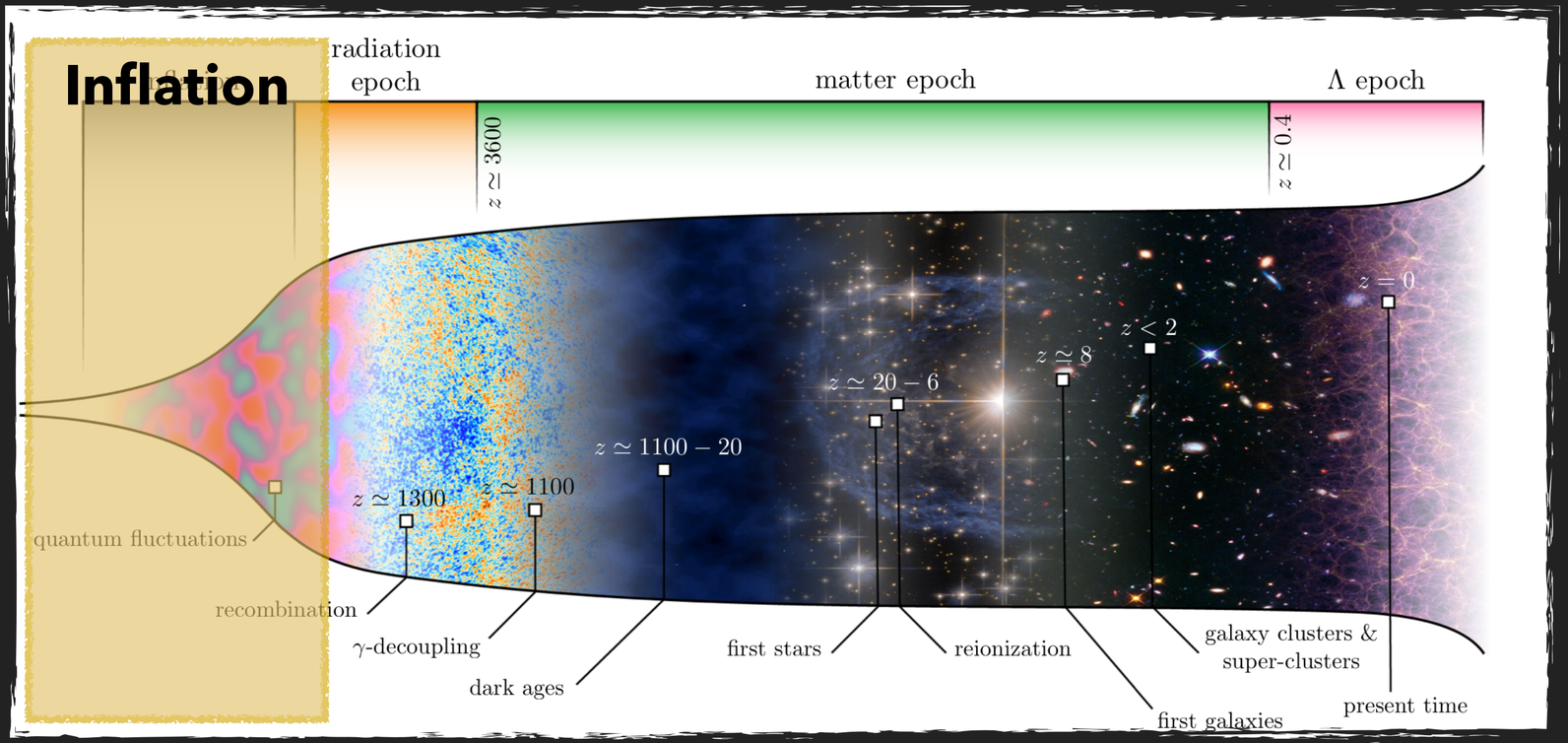
- All evidence for DM comes from *gravitational* interactions
- Searches for DM rely on other interactions with SM
- Production mechanisms can guide experimental searches

PRODUCTION MECHANISMS AS A GUIDE IN PARAMETER SPACE



- Many production mechanisms rely on non-gravitational interactions

GRAVITATIONAL PRODUCTION OF DM



- Successful paradigm of Primordial Inflation
- Time-varying background, large $H \Longrightarrow$ particle production
- Unavoidable contribution; could account for DM?

GRAVITATIONAL PRODUCTION

['39 Schrödinger; '69 Parker;
'77 Gibbons, Hawking;
'79 Birrell, Davies; '87 Ford; ...]

GRAVITATIONAL PRODUCTION

Time-varying bkg $\Longrightarrow \dfrac{\dot{\omega}}{\omega^2} > 1$ non-adiabaticity $\Longrightarrow$ particle prod.

$\omega_k(t) \rightsquigarrow$ mass term, ...

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(approximate analogy)

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	$\rho_{\rm exit} \sim$
Scalar, Massive Vector	H_I^4
Massive Fermion	$m^2 H_I^2$

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$m_{\rm DM}$ RANGE FOR GRAVITATIONAL PRODUCTION

Single Species

Massive vector A'_L

['15 Graham, Mardon, Rajendran]

Fermion ψ

['98 Chung, Kolb, Riotto]

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Dark Sector

MASSIVE DARK QED

ψ Dark Matter

A'_L grav. prod.

['21 Arvanitaki, Dimopoulos, Galanis, **DR**, Simon, Thompson]

- A minimal complexity of the dark sector opens new benchmarks!

VECTOR DARK MATTER — LONGITUDINAL A'_L

['15 Graham, Mardon, Rajendran]

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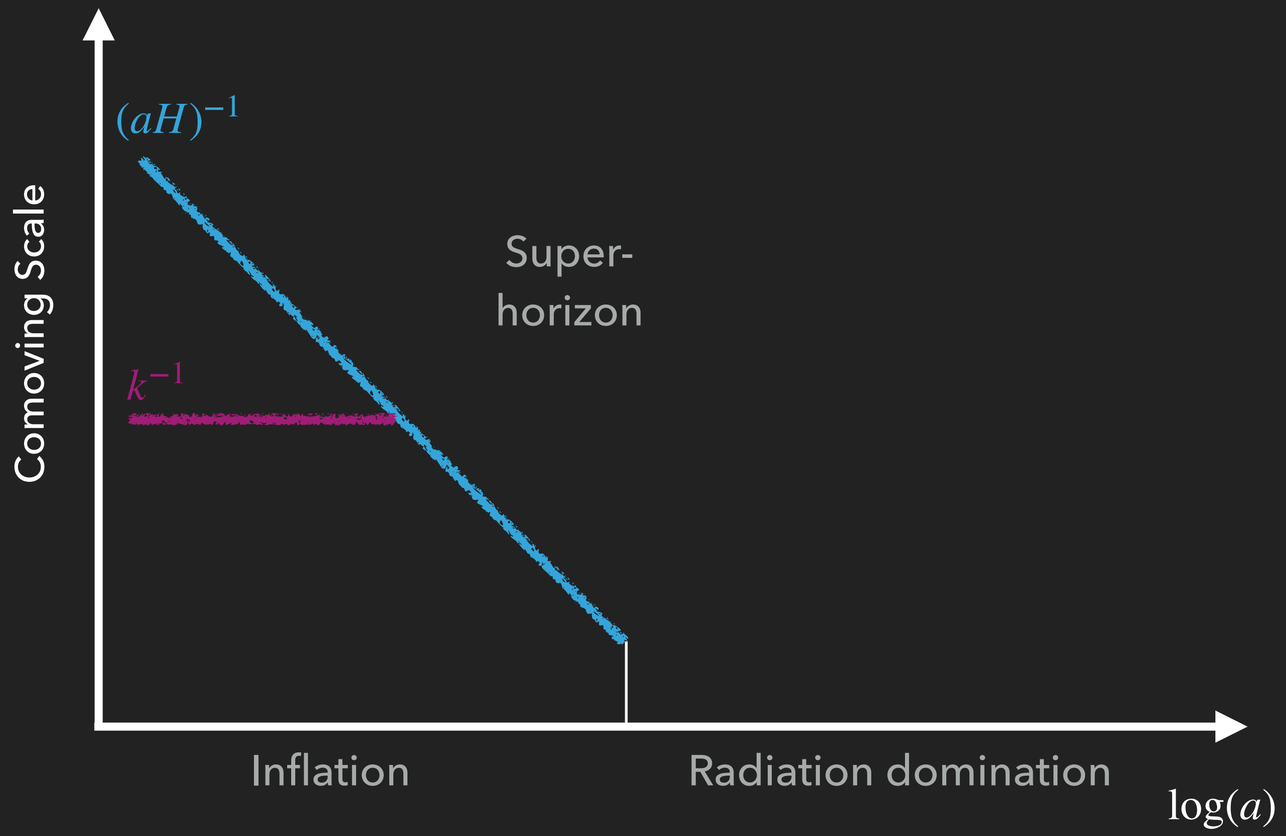

- $\rho_{k,\text{exit}} \sim H_I^4$, the mode $A'_{L,k}$ freezes

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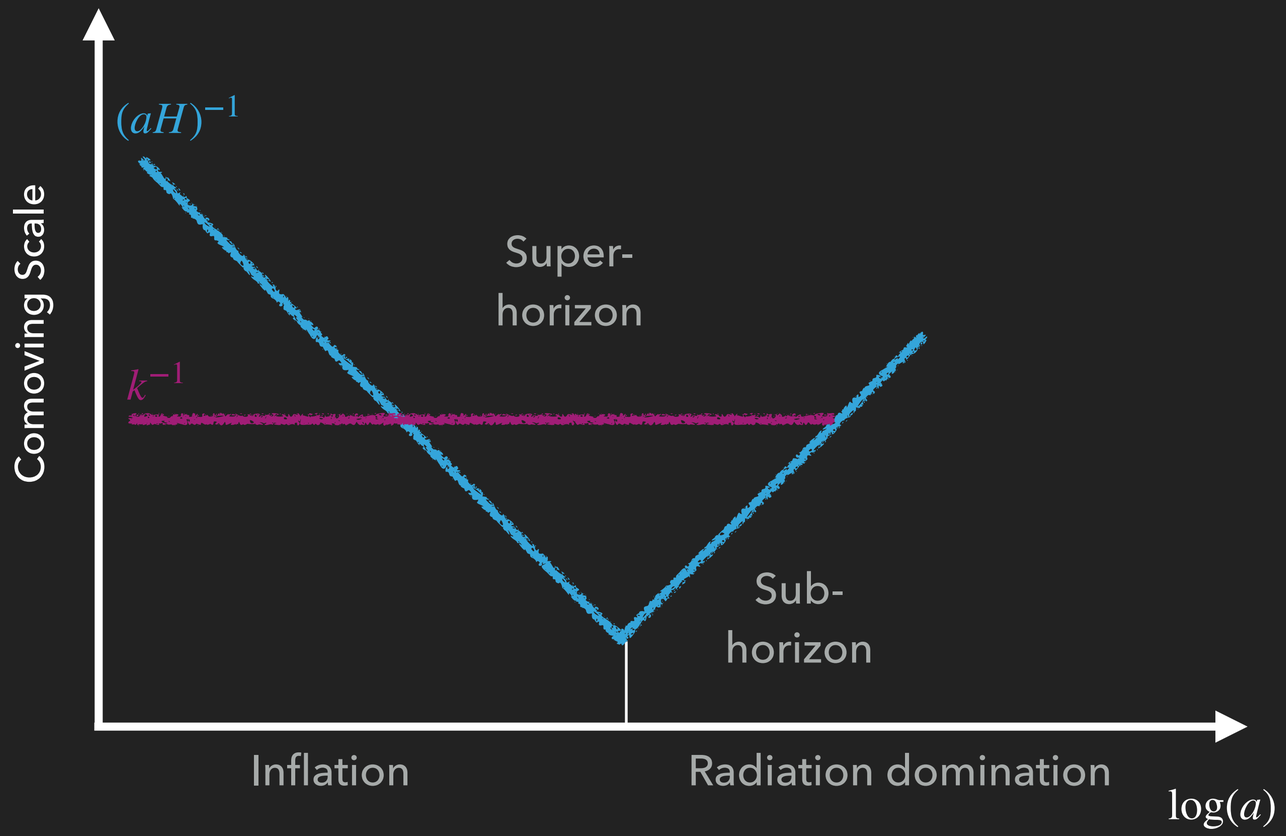

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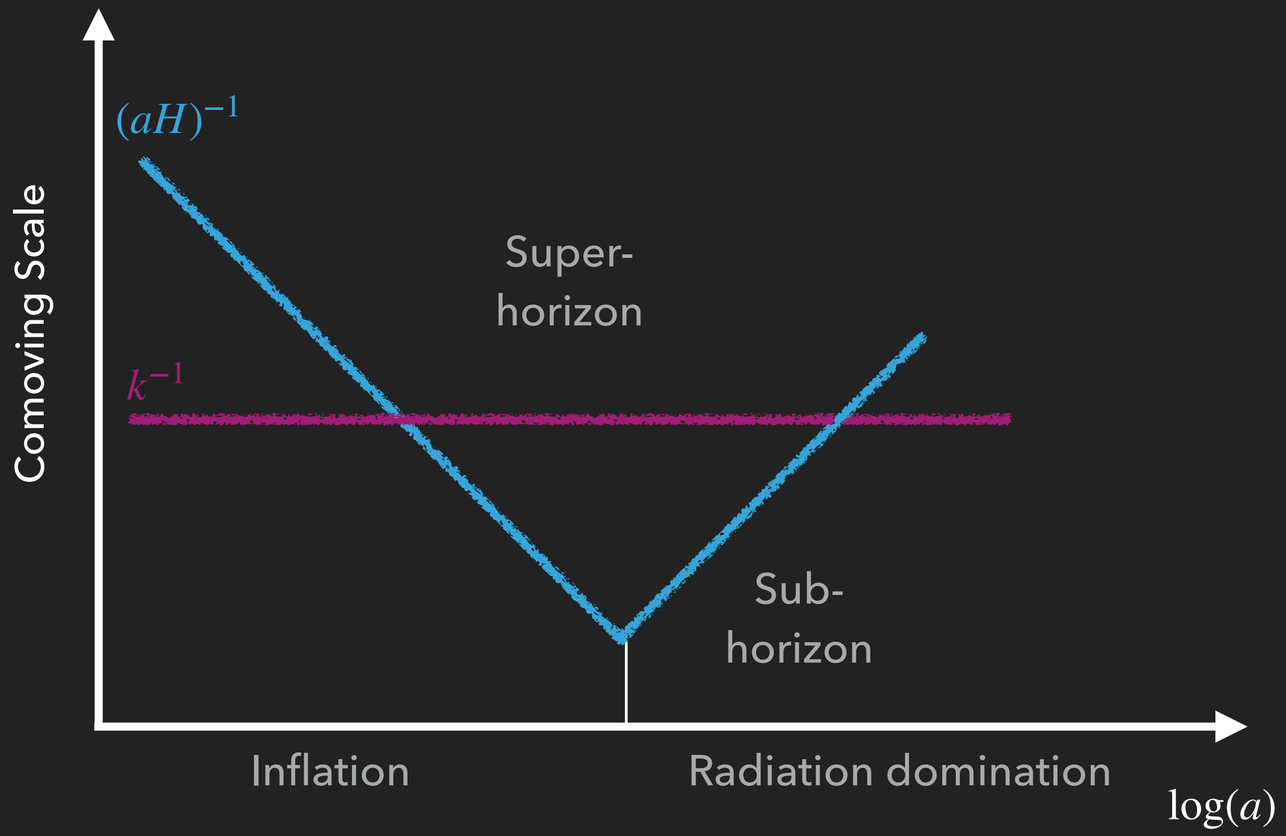

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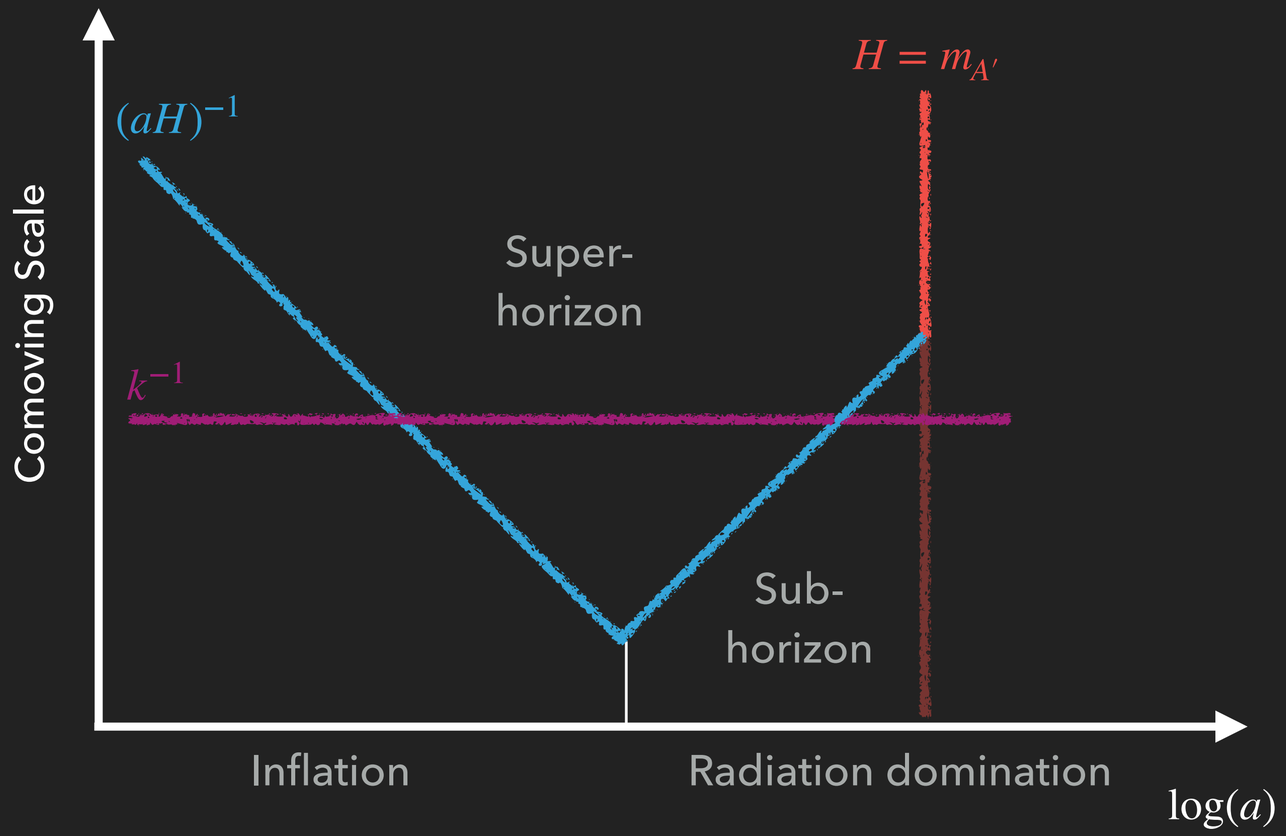

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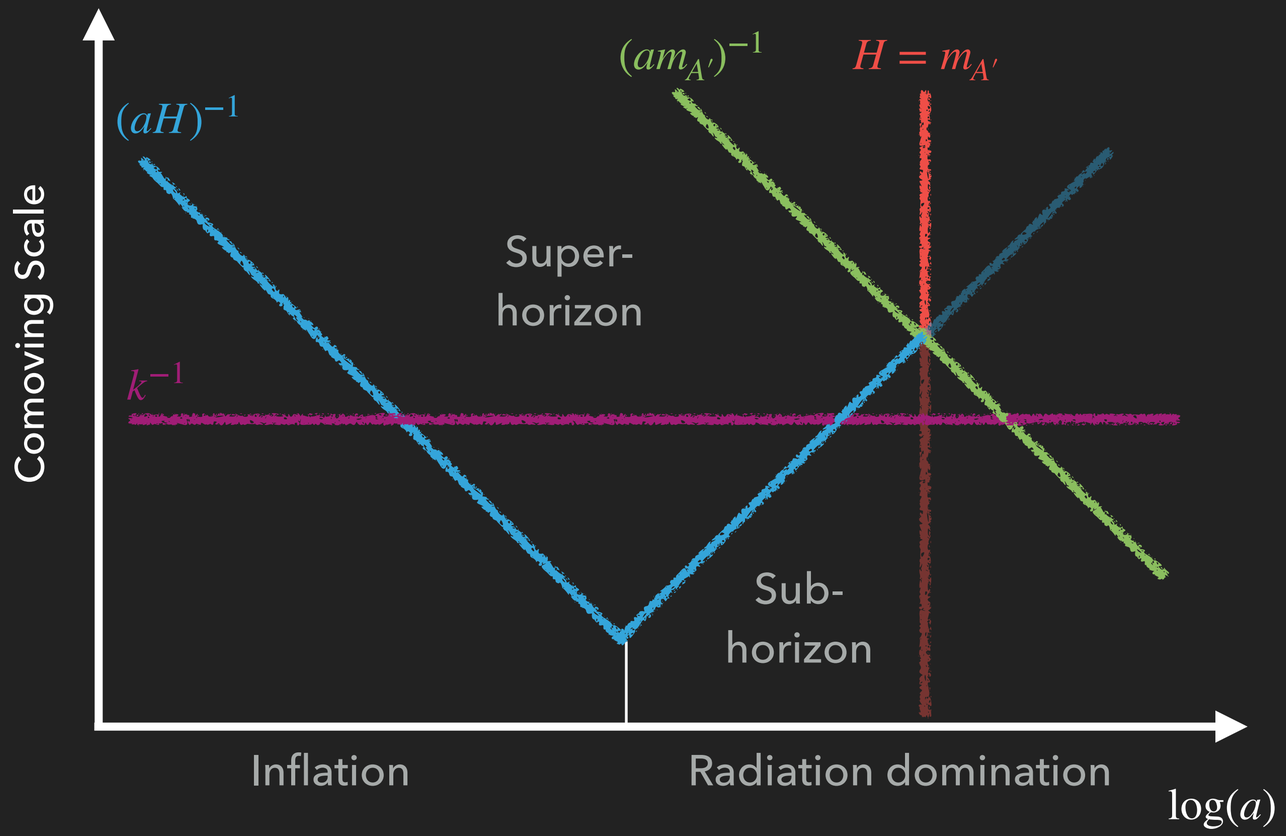

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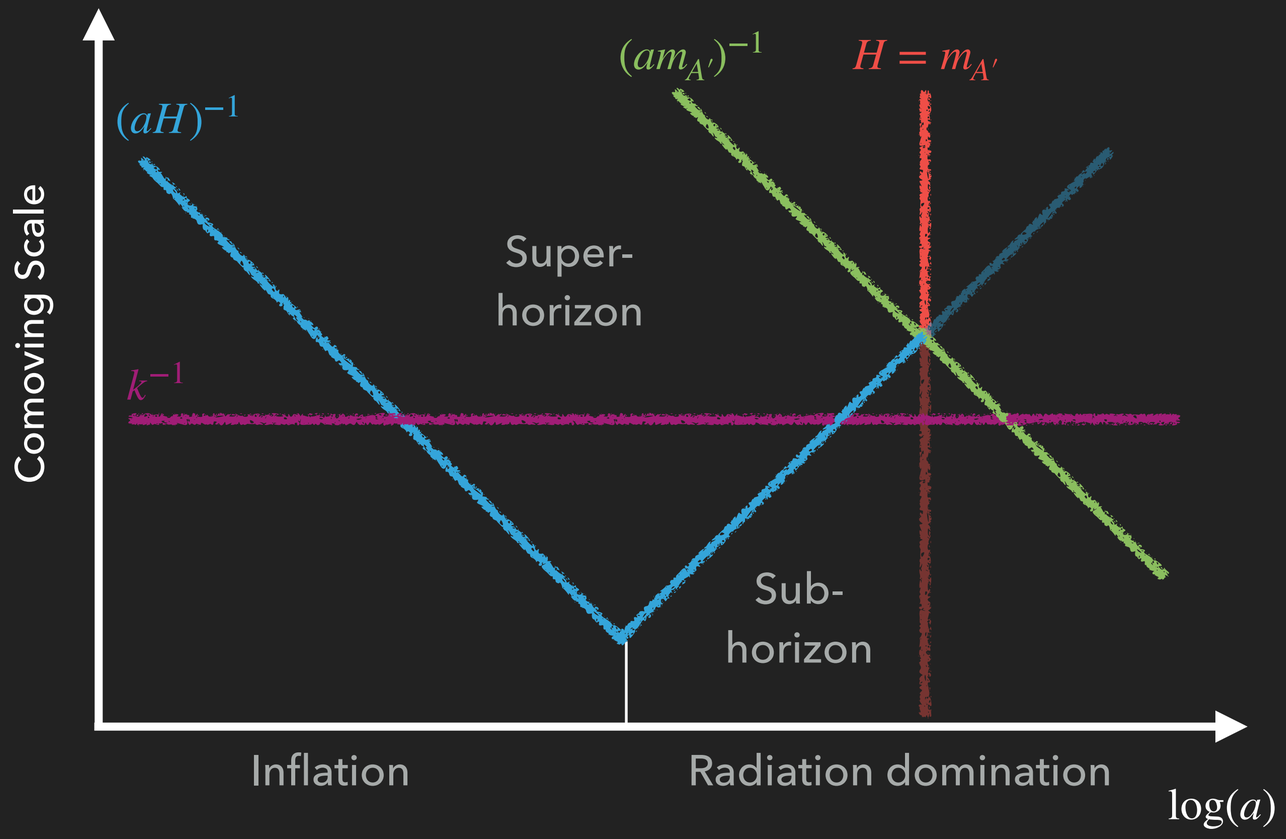

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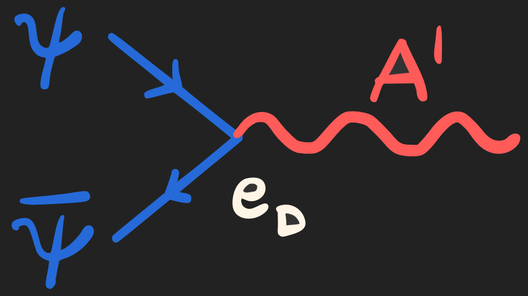
$$\frac{\Omega_{A'}}{\Omega_{\text{DM}}} \sim \sqrt{\frac{m_{A'}}{5 \cdot 10^{-5}\,\text{eV}}} \left(\frac{H_I}{6 \cdot 10^{13}\,\text{GeV}}\right)^2$$

GRAVITATIONAL PRODUCTION IN A DARK SECTOR

['21 Arvanitaki, Dimopoulos, Galanis, **DR**, Simon, Thompson]

Dark Sector → MASSIVE DARK QED



- In this talk, for illustration, $m_\psi \gg m_{A'}$

A'_L gravitationally produced during inflation → (Frozen Super-Horizon) → Horizon crossing: $A'_L \to A'_T, \psi$ → (Thermalisation) → Dark sector $T_{\rm DS} \sim \sqrt{\frac{H_I}{M_P}} T_{\rm SM}$ → (Freeze–out) → ψ Dark Matter

$$m_\psi \in [\mathrm{GeV}, 10\,\mathrm{TeV}] \cdot \left(\frac{6 \cdot 10^{13} \mathrm{GeV}}{H_I} \right)^{1/4}$$

DARK MASSIVE QED

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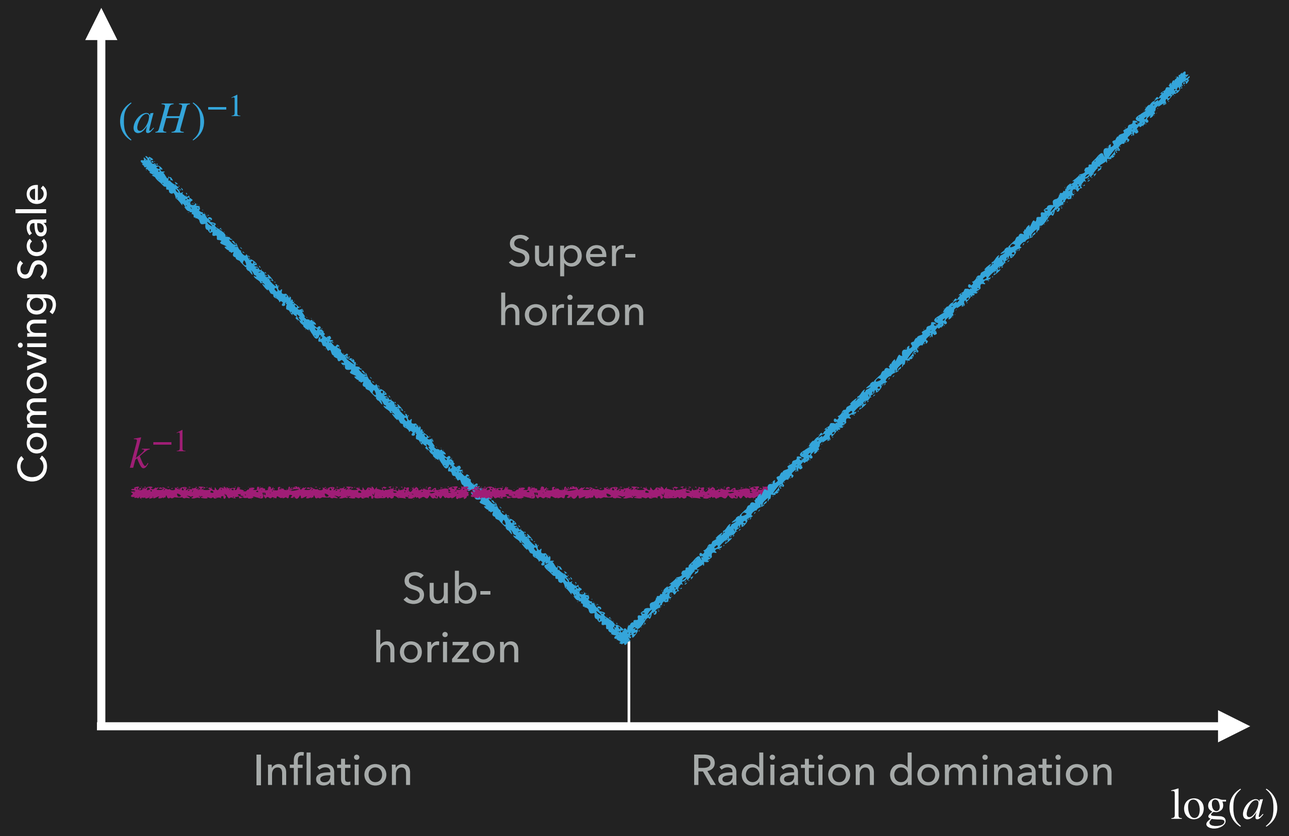

- $A'_{L,k}$ produced during inflation

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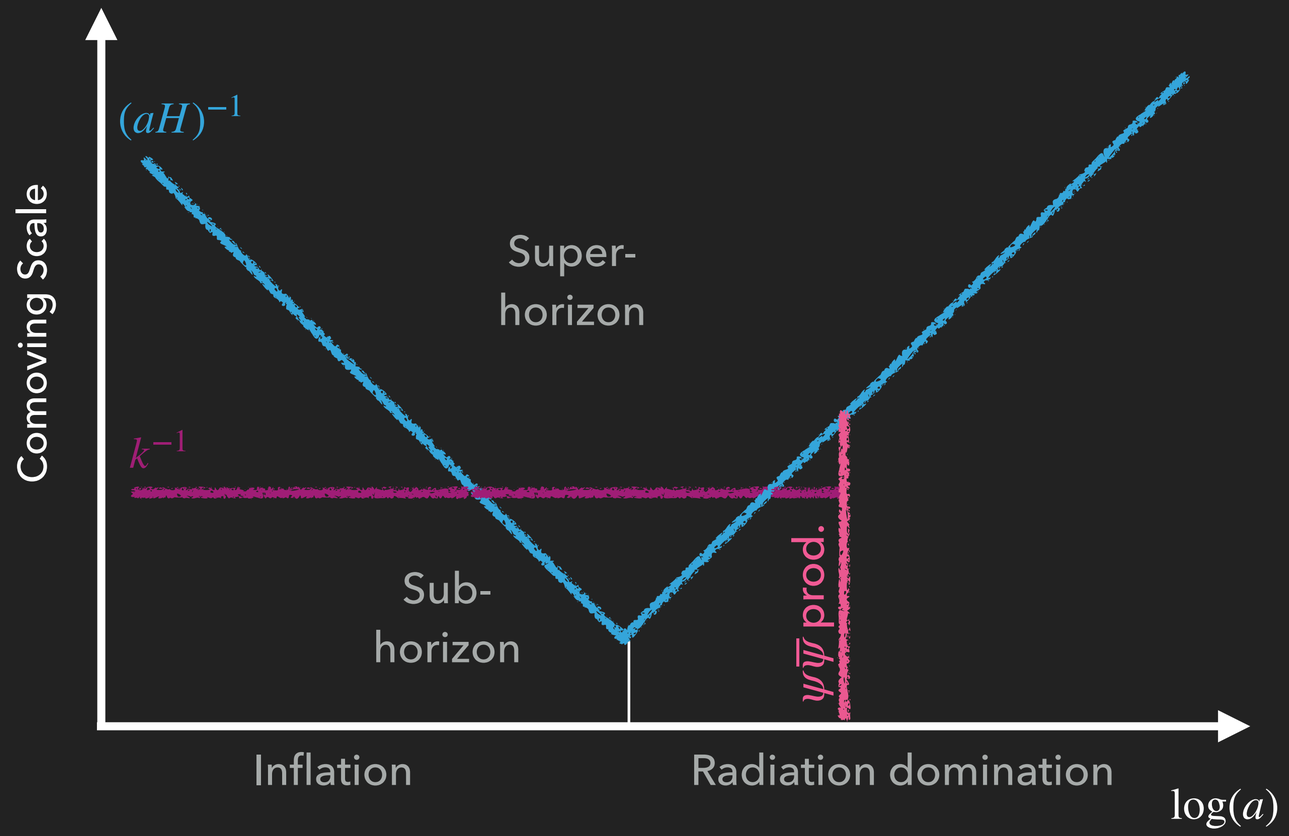
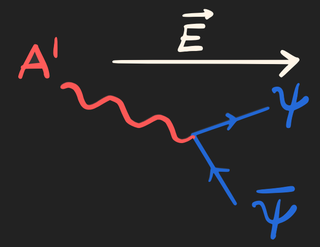


- $A'_{L,k}$ produced during inflation
- Hor. crossing: strong electric fields



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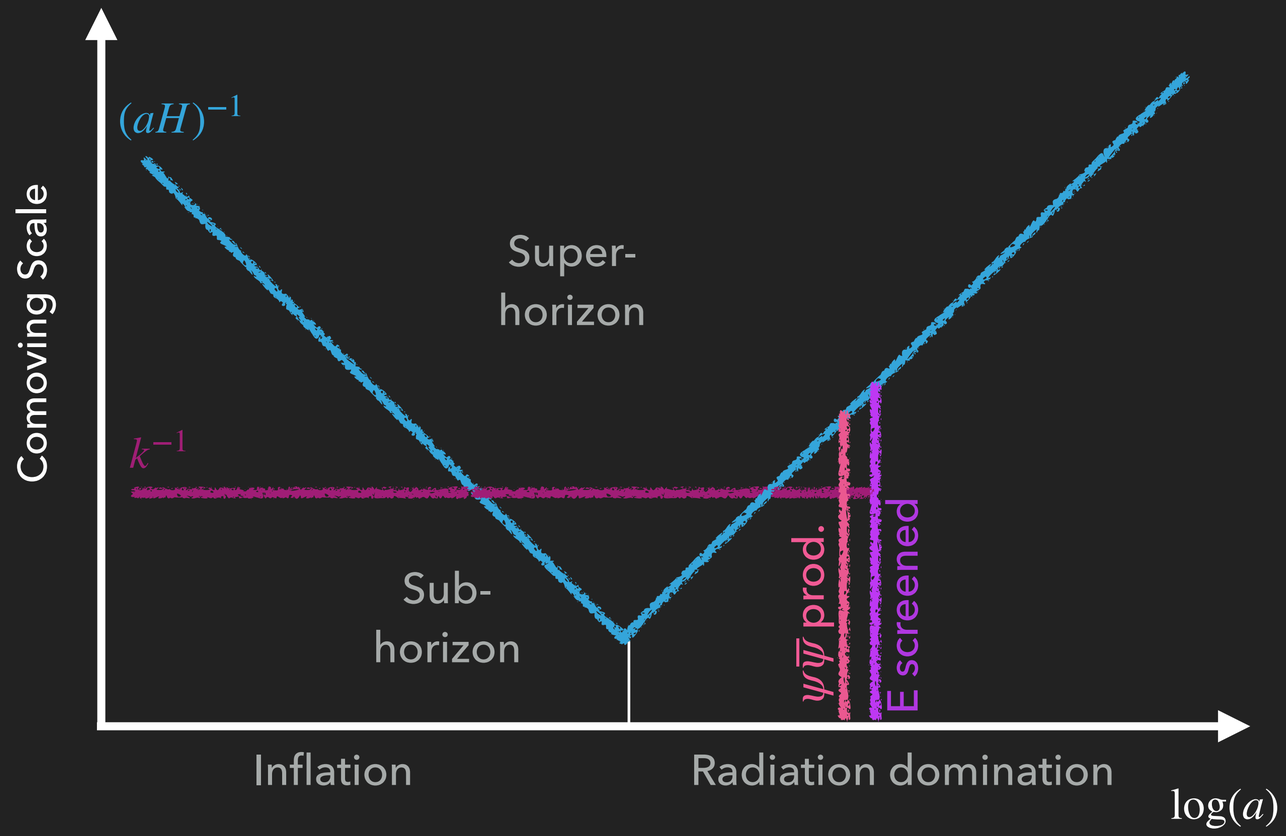

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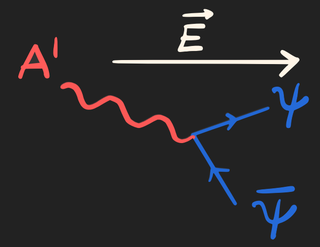

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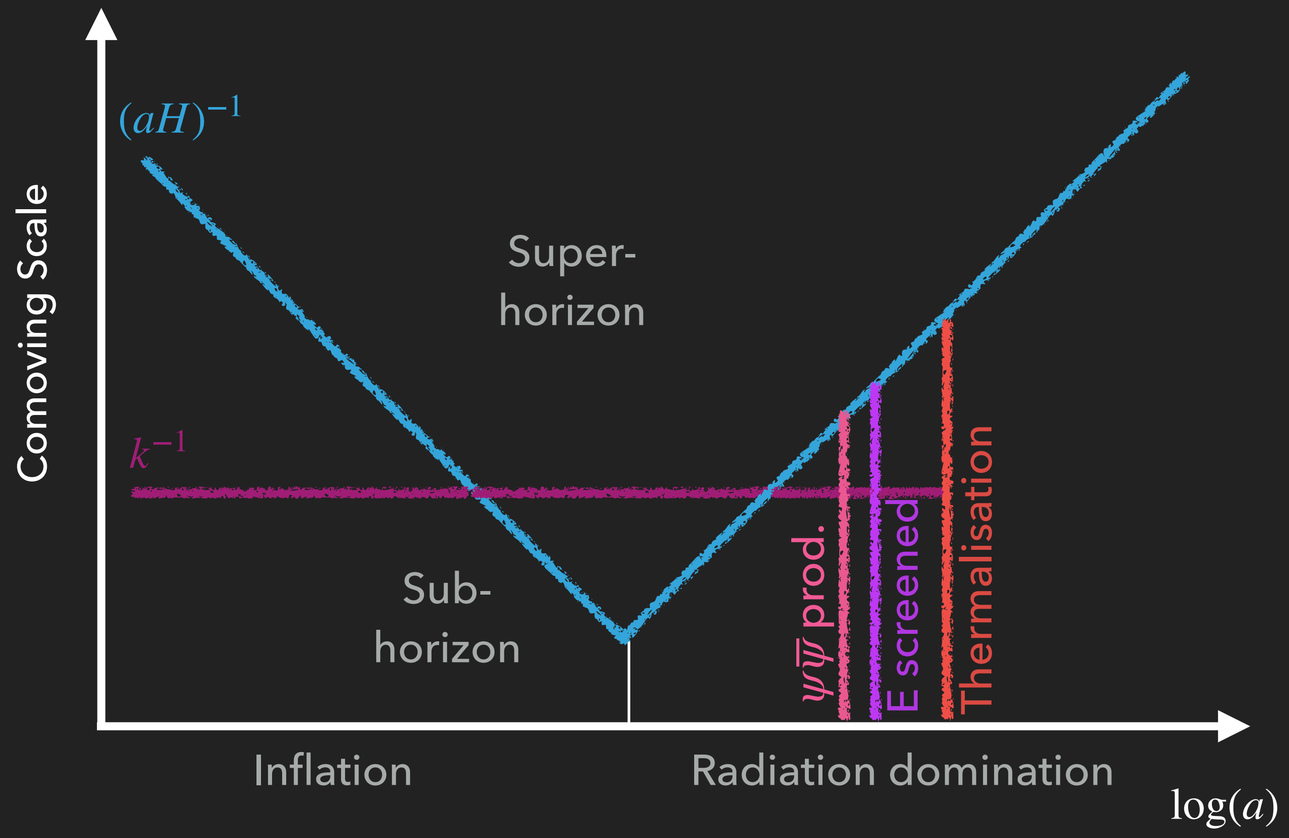

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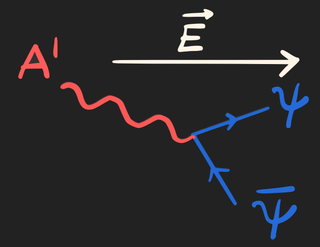

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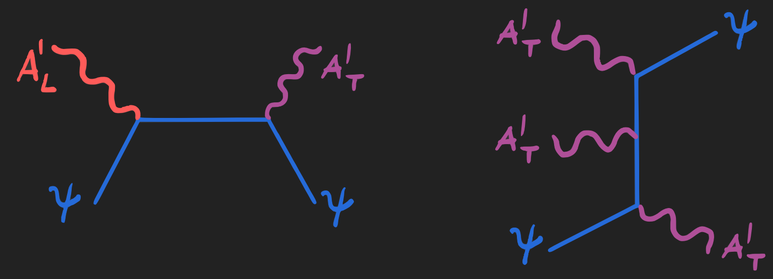

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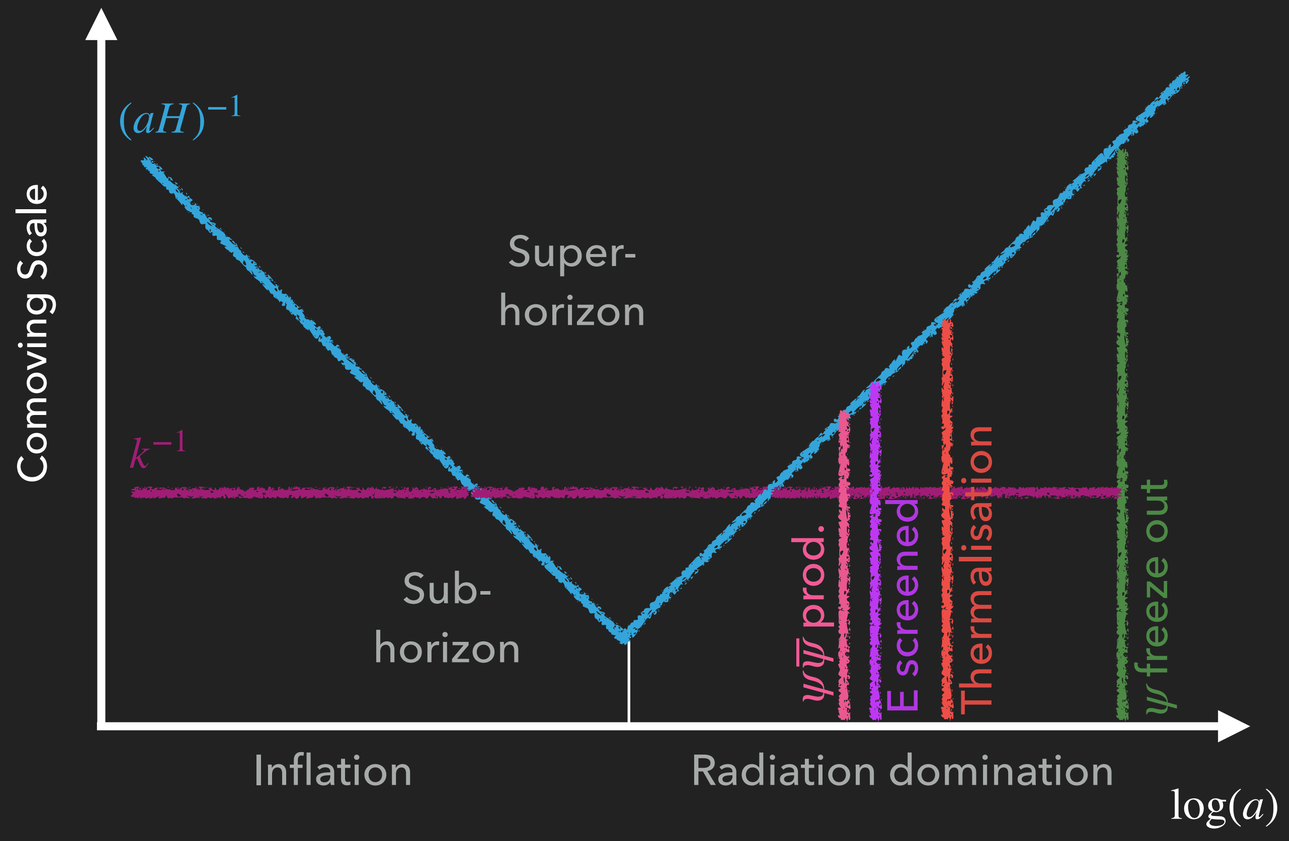

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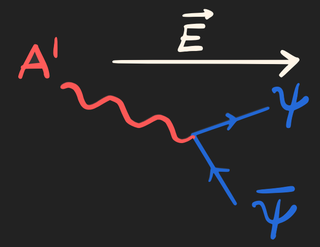

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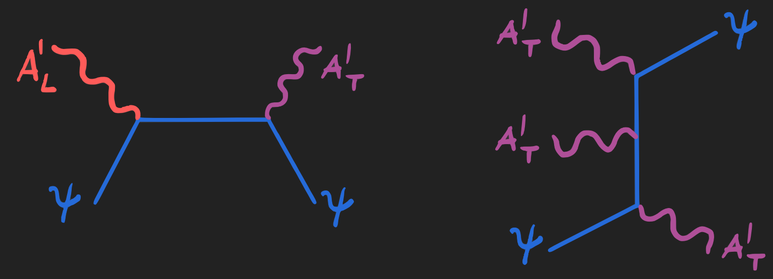
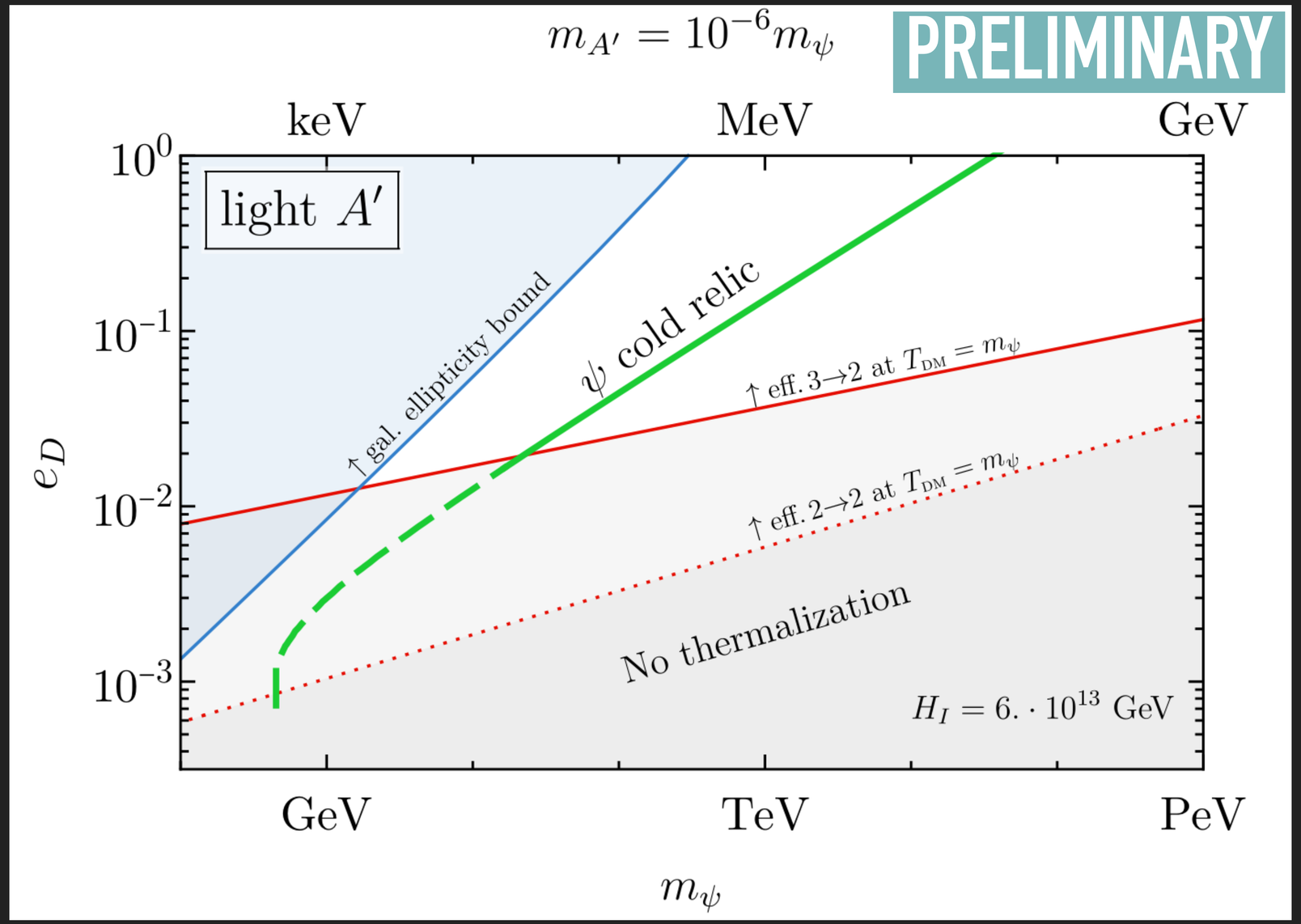


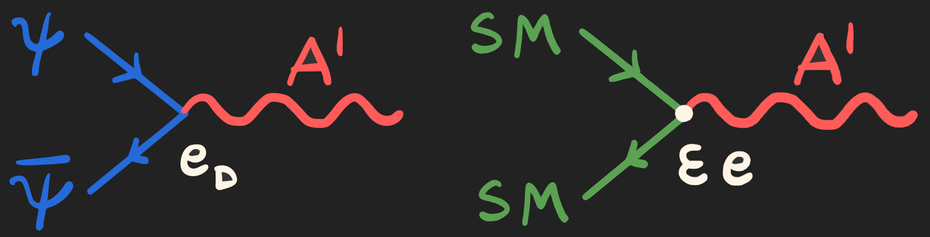
- ψ's freeze out ⟶ Dark Matter

PARAMETER SPACE FOR DARK QED

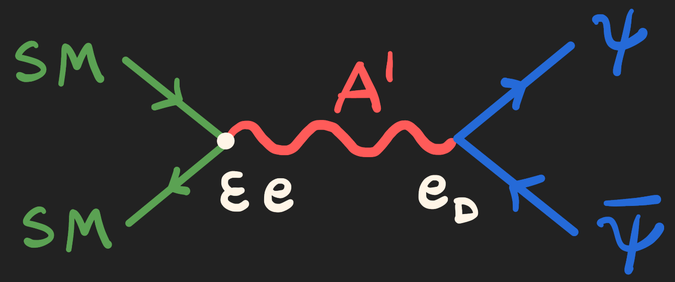


INCLUDING KINETIC MIXING $A' - A$

- $\varepsilon F'_{\mu\nu} F^{\mu\nu}$ is generically present



- Handle for DM detection
- Production via **freeze–in**:



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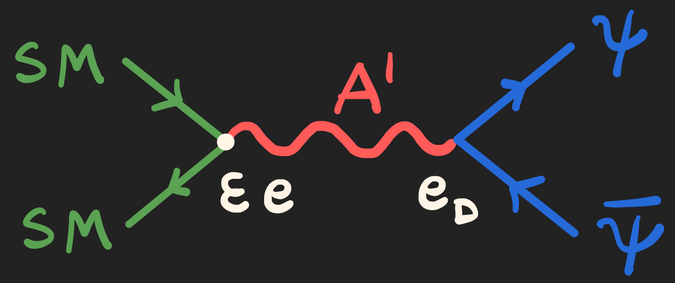
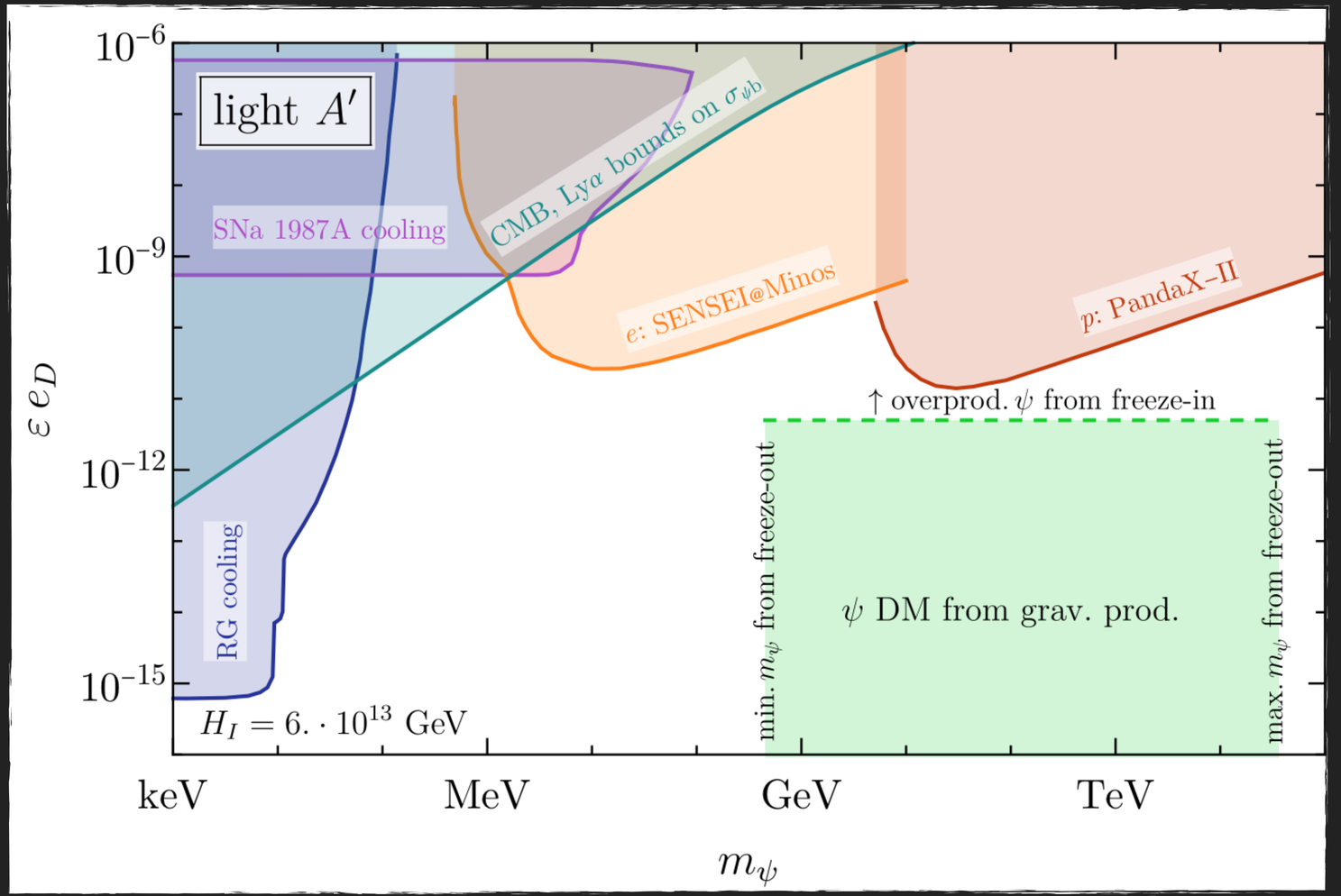


- Grav. prod. in massive QED complements freeze-in

PRELIMINARY



CONCLUSIONS

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- Gravity + inflation $\Longrightarrow$ unavoidable gravitational production

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- Minimal structure in dark sector opens up new benchmarks for detection