CITA
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Canadian Institute for
Theoretical Astrophysics

L'institut Canadien
d'astrophysique théorique

Generating and Constraining Primordial Magnetic Fields

Takeshi Kobayashi (CITA)

based on arXiv:1403.5168,
arXiv:1408.4141 (w/ Niayesh Afshordi)

The 6th KIAS Workshop on
Cosmology and Structure Formation

OUR MAGNETIZED UNIVERSE

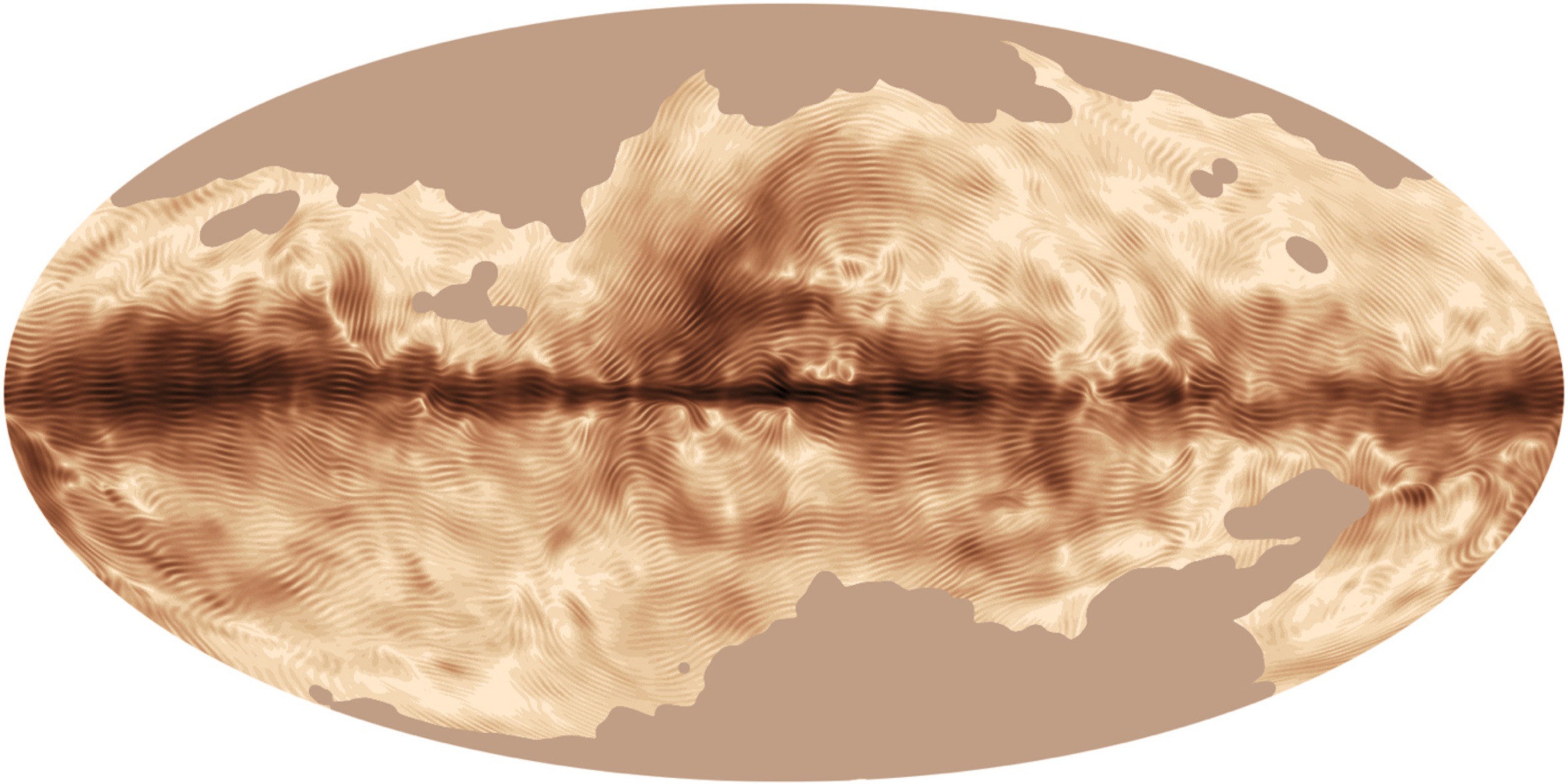

image : ESA and the Planck Collaboration

BLAZAR OBSERVATIONS

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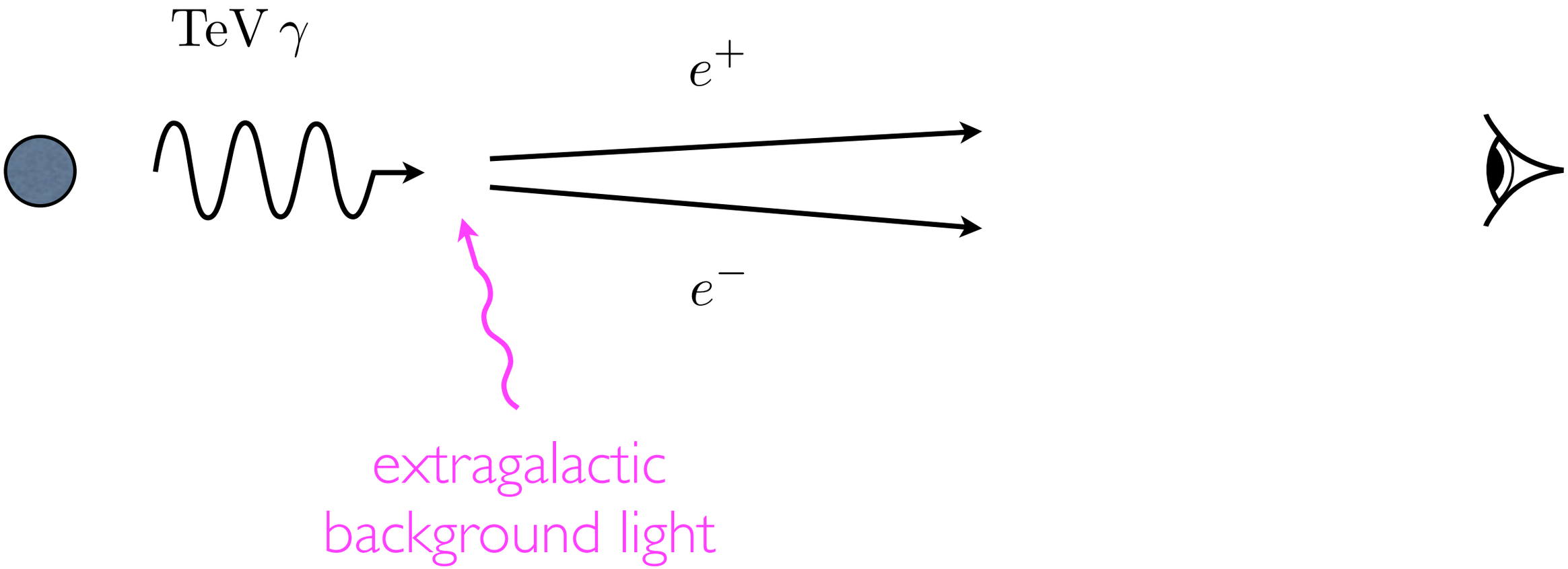

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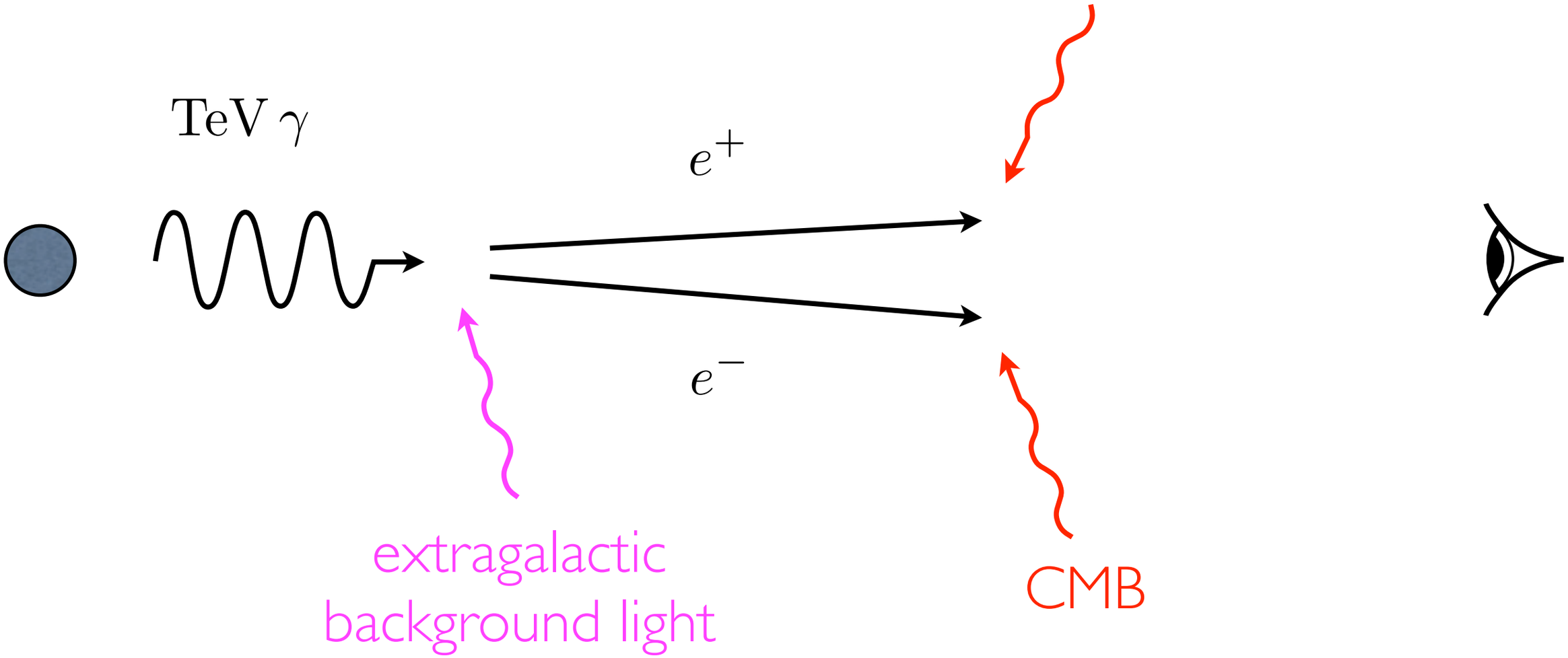

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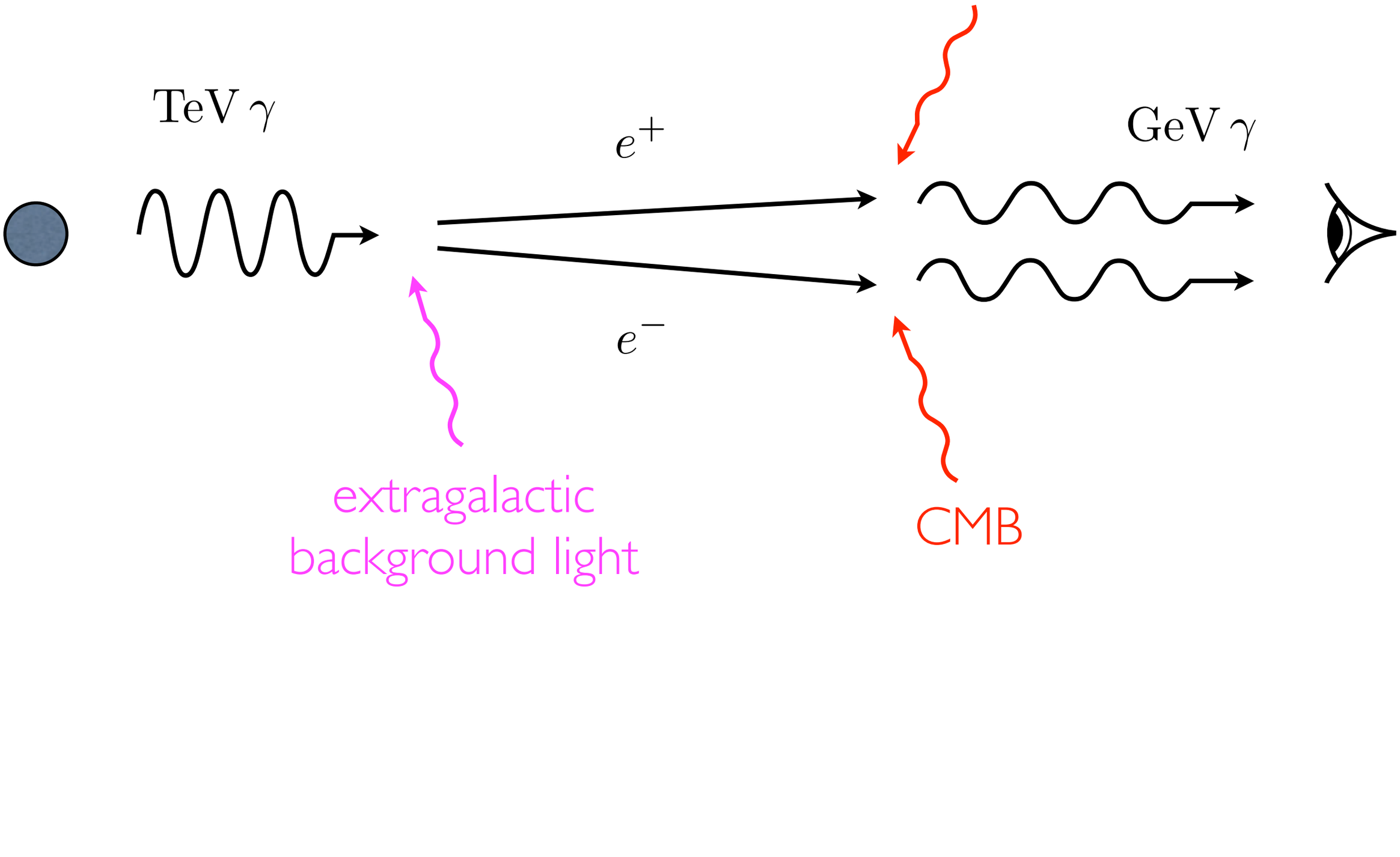

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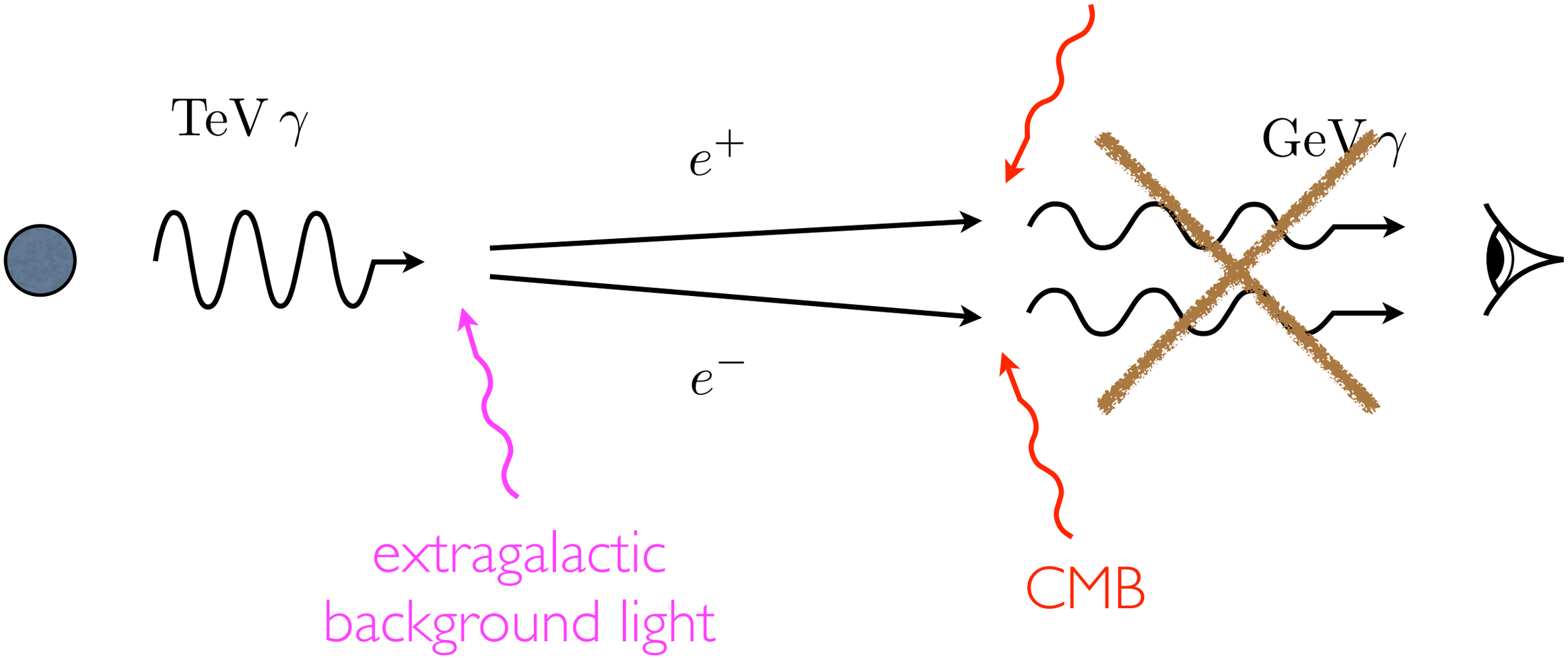

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With intergalactic magnetic fields...

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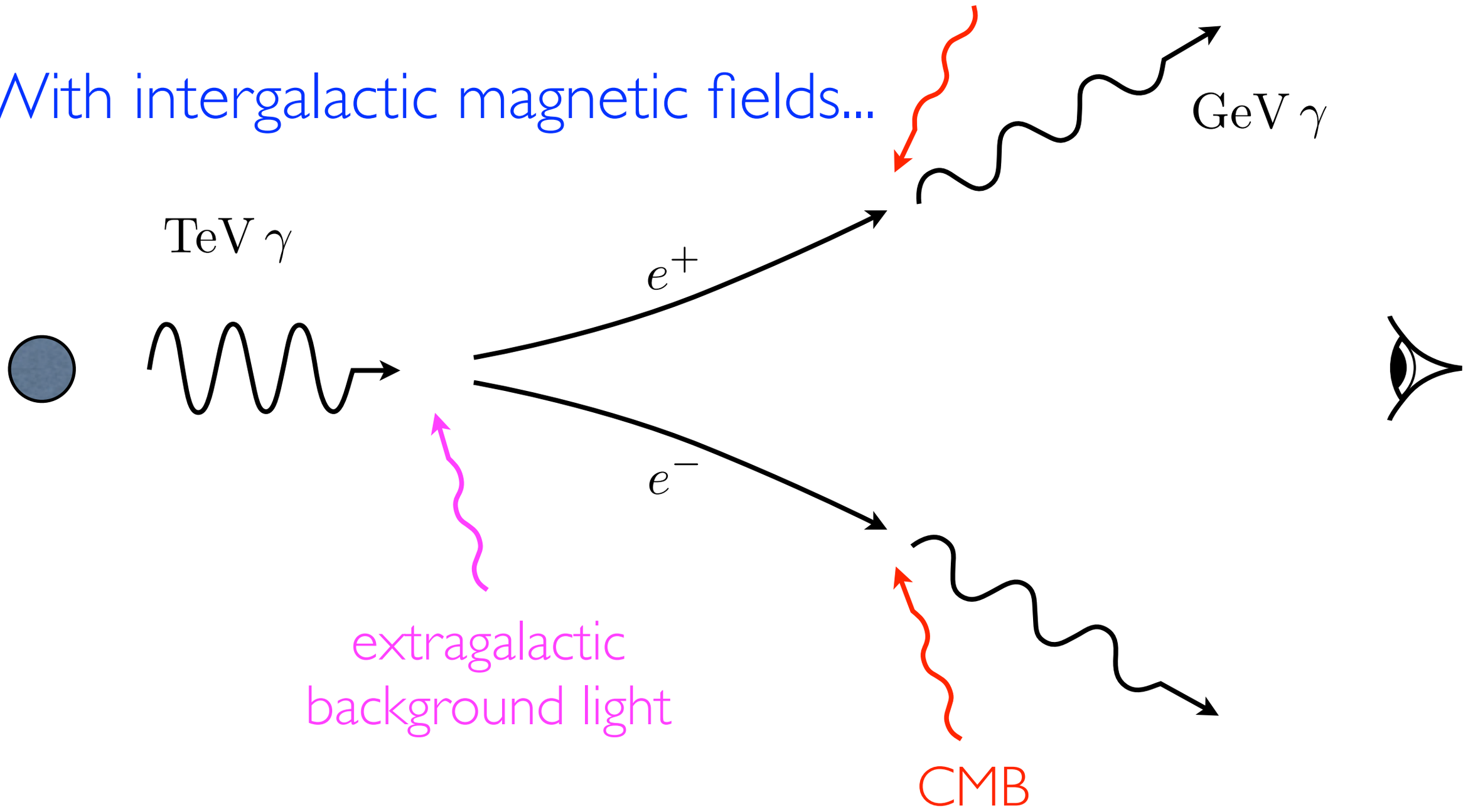

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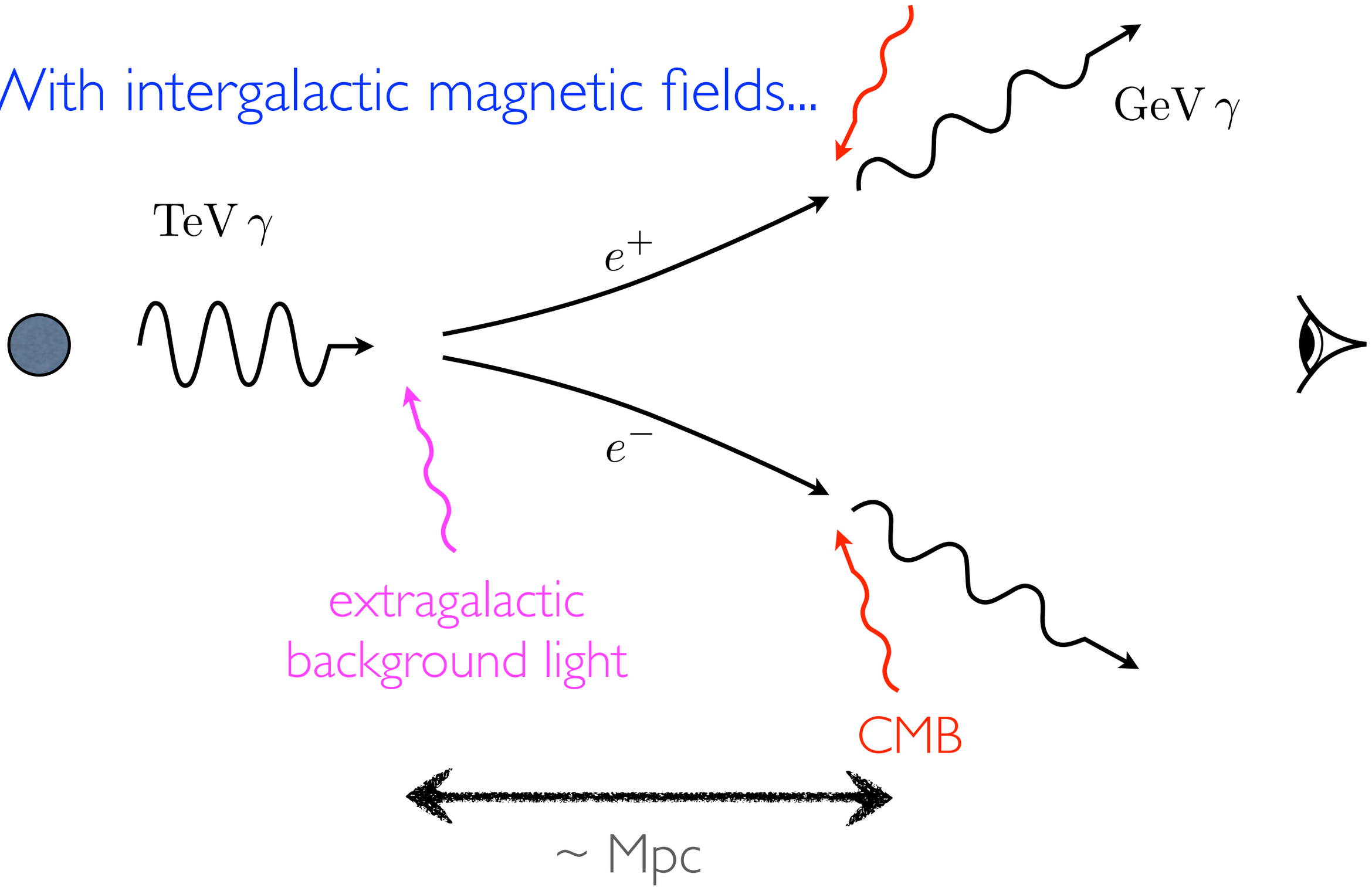

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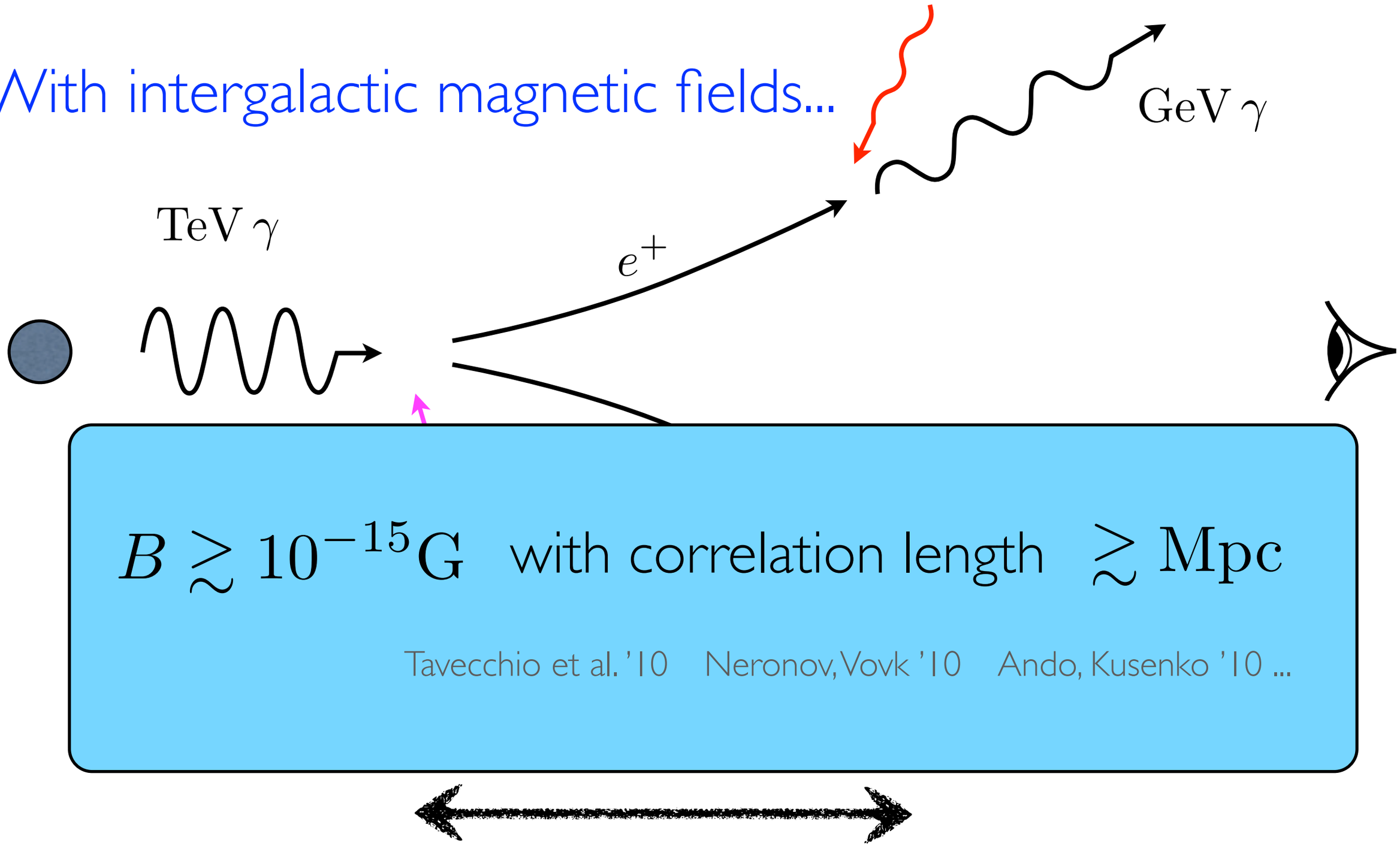

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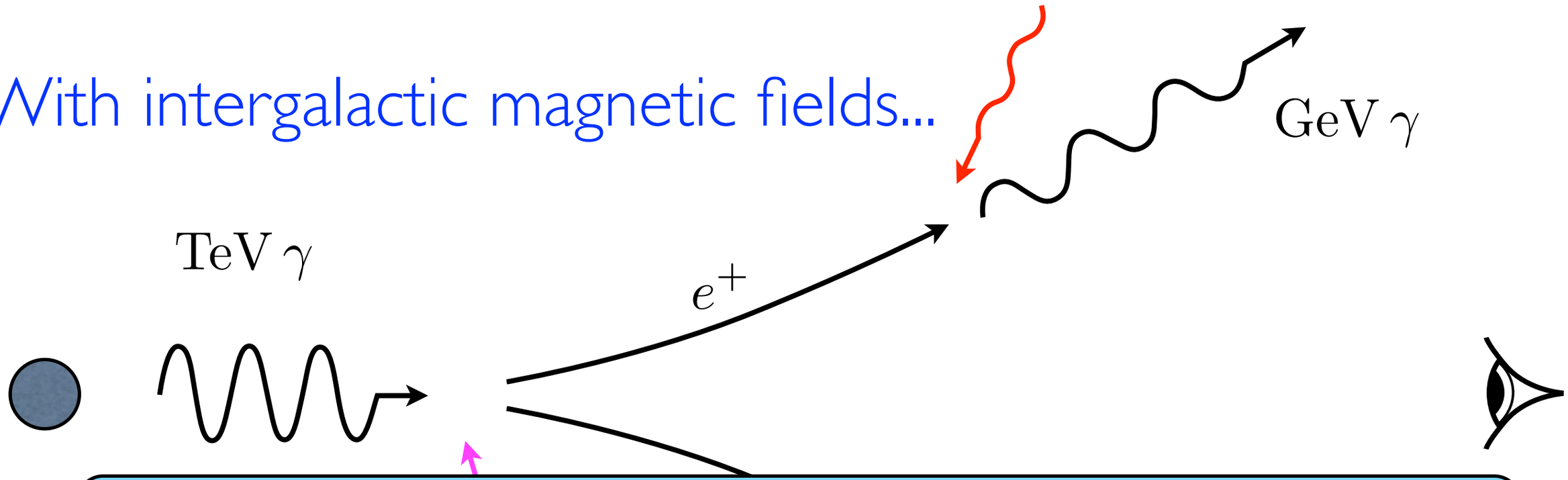

Can primordial magnetic fields be this large?

OUTLINE

- Constraints on Primordial Magnetic Fields from Schwinger Effect

  arXiv:1408.4141 w/ N. Afshordi

- New Idea for Magnetic Field Generation: Post-Inflationary Magnetogenesis

  arXiv:1403.5168

COSMOLOGICAL PRODUCTION OF MAXWELL FIELDS

$$\frac{\mathcal{L}}{\sqrt{-g}} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

conformal symmetry : $g_{\mu\nu} \to \Omega^2 g_{\mu\nu}$

COSMOLOGICAL PRODUCTION OF MAXWELL FIELDS

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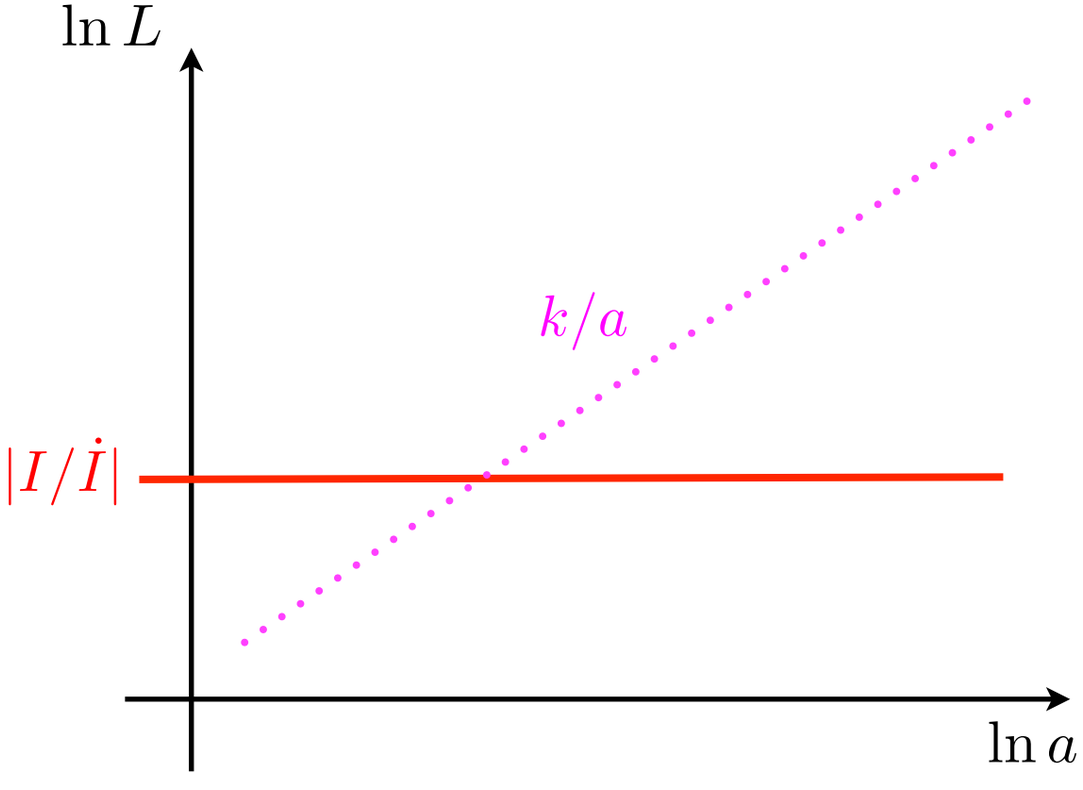
INFLATIONARY MAGNETOGENESIS

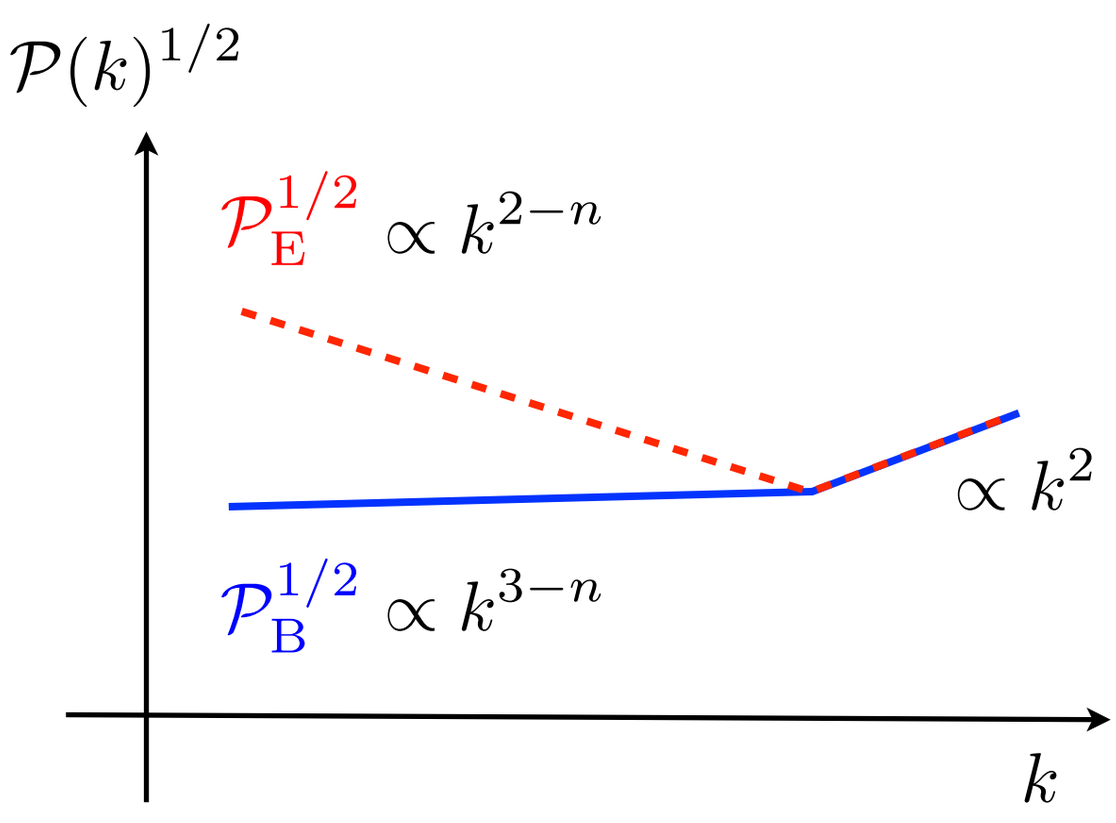
Turner, Widrow '88 Ratra '92

conformal symmetry breaking during inflation

$$\frac{\mathcal{L}}{\sqrt{-g}} = -\frac{I(\sigma)^2}{4} F_{\mu\nu} F^{\mu\nu}$$



($I \propto a^{-n}$ during inflation)



HOWEVER...

- magnetogenesis also generates electric fields

- large electric fields induce conductivity in the inflating universe via Schwinger effect

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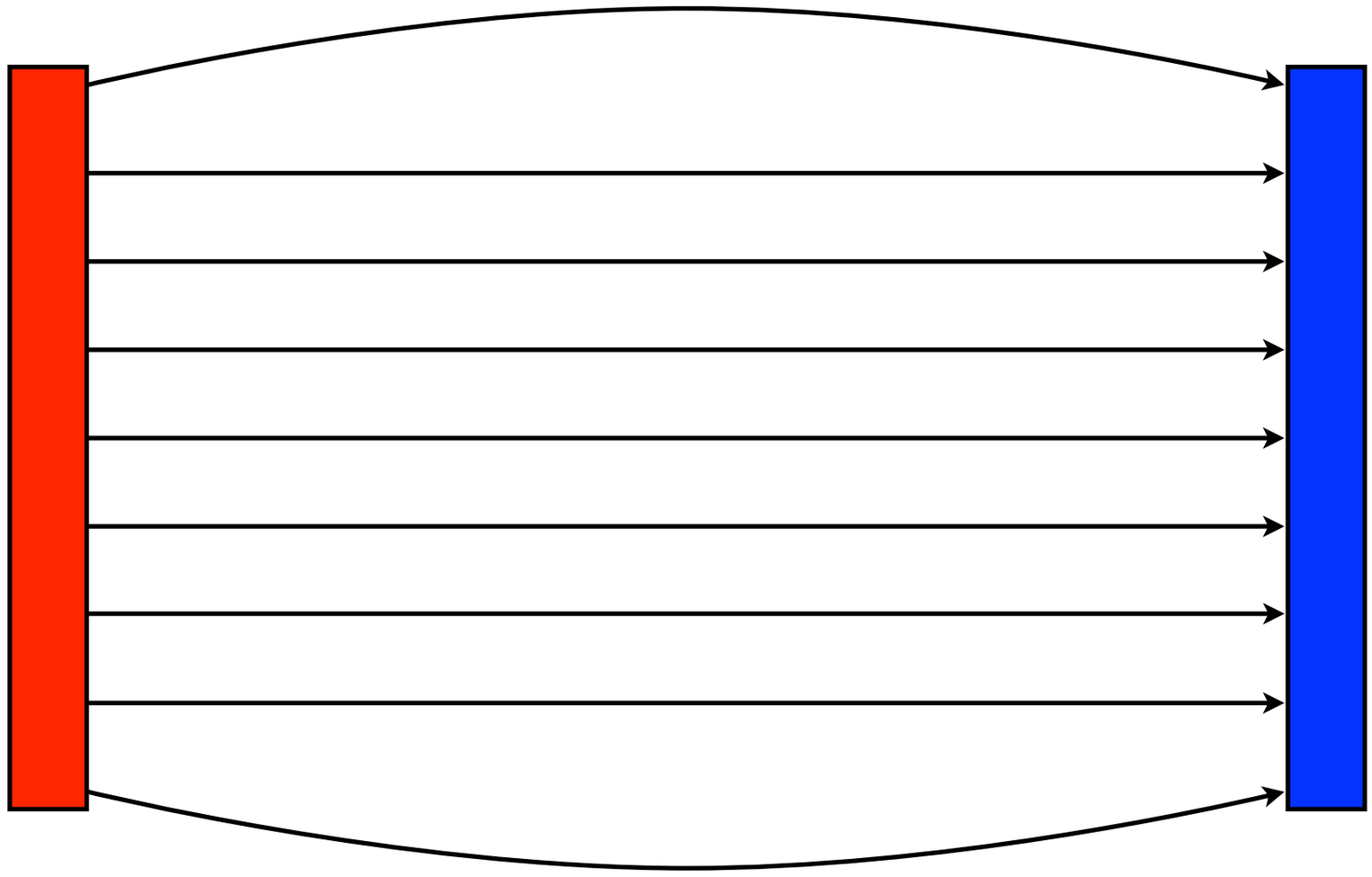
→ Magnetic field generation eventually saturates!

SCHWINGER EFFECT

Sauter '31 Heisenberg, Euler '36 Schwinger '51

creation of charged particle pairs under strong electric fields



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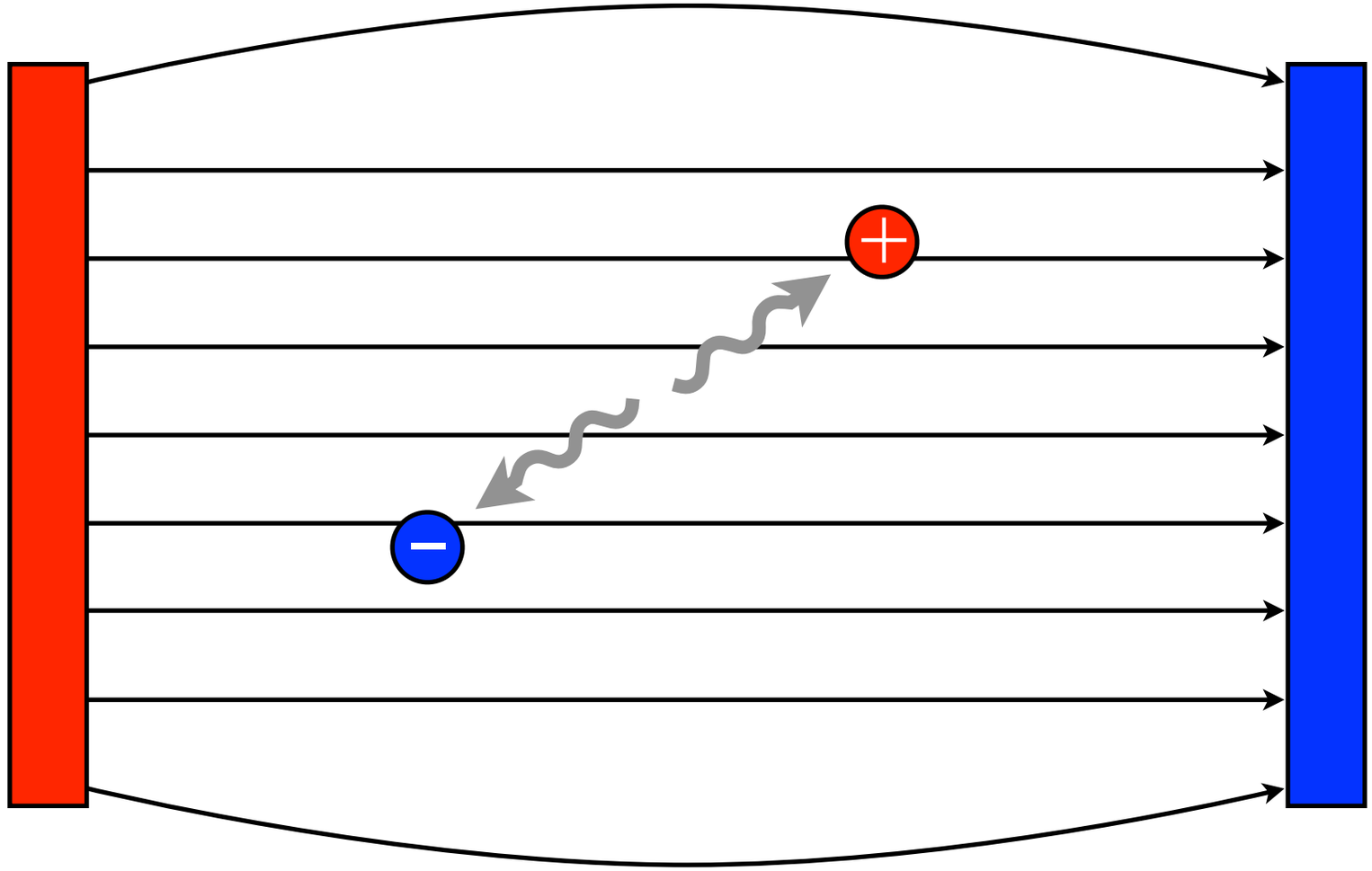

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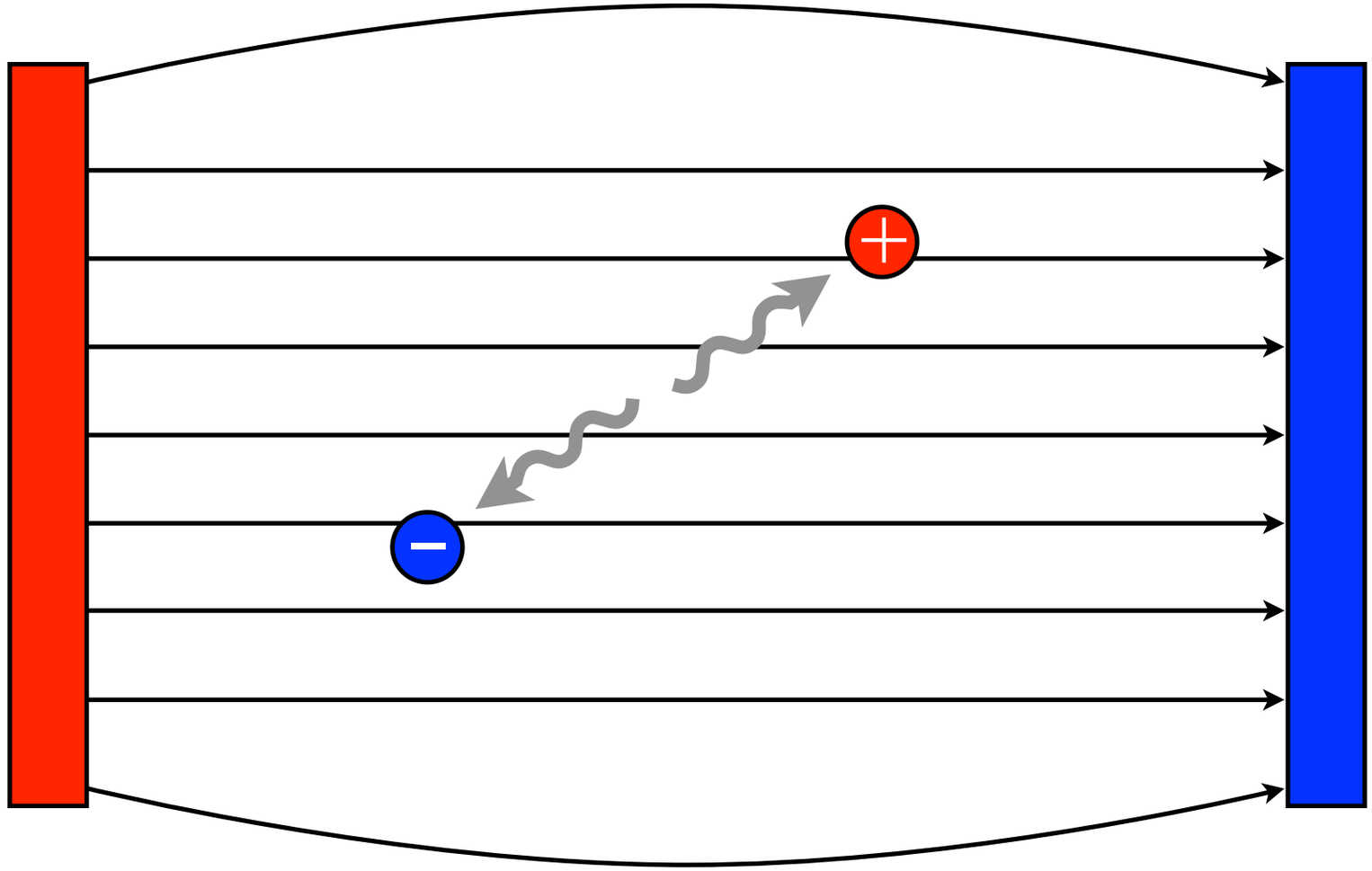
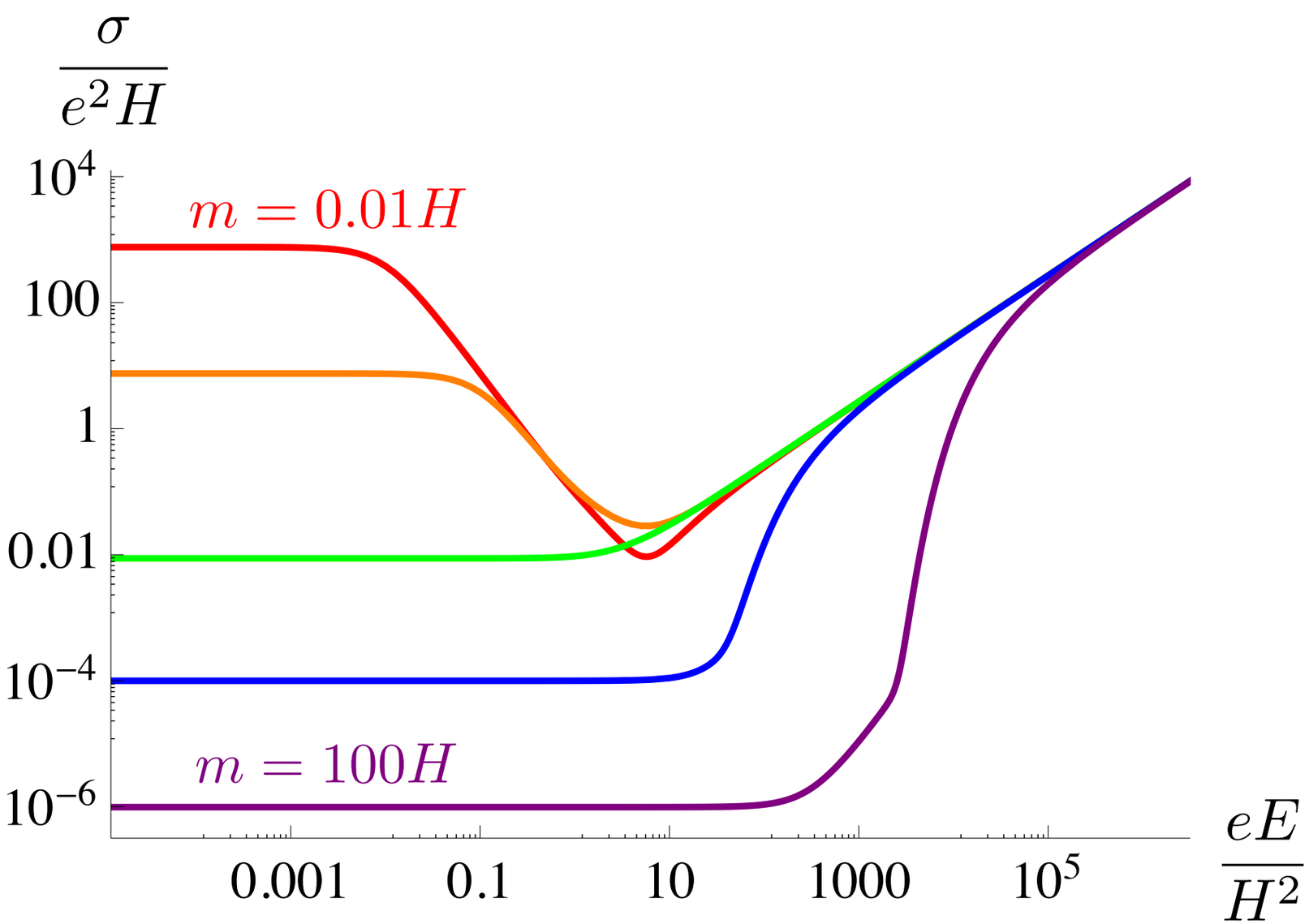


In an inflating universe, there is further gravitational particle creation.

CONDUCTIVITY OF DE SITTER UNIVERSE FROM SCHWINGER EFFECT



Schwinger production of fields with charge e and mass m

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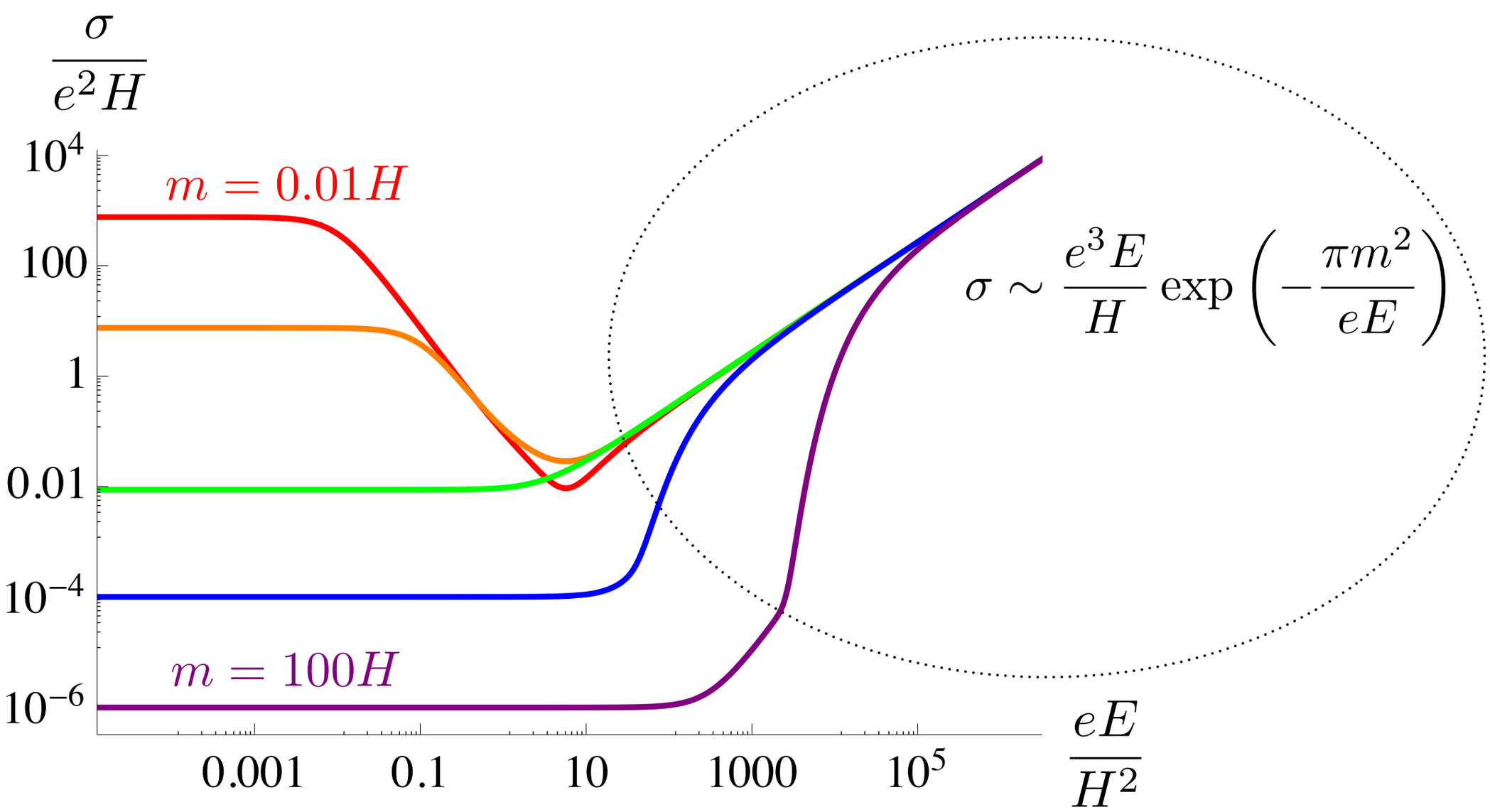

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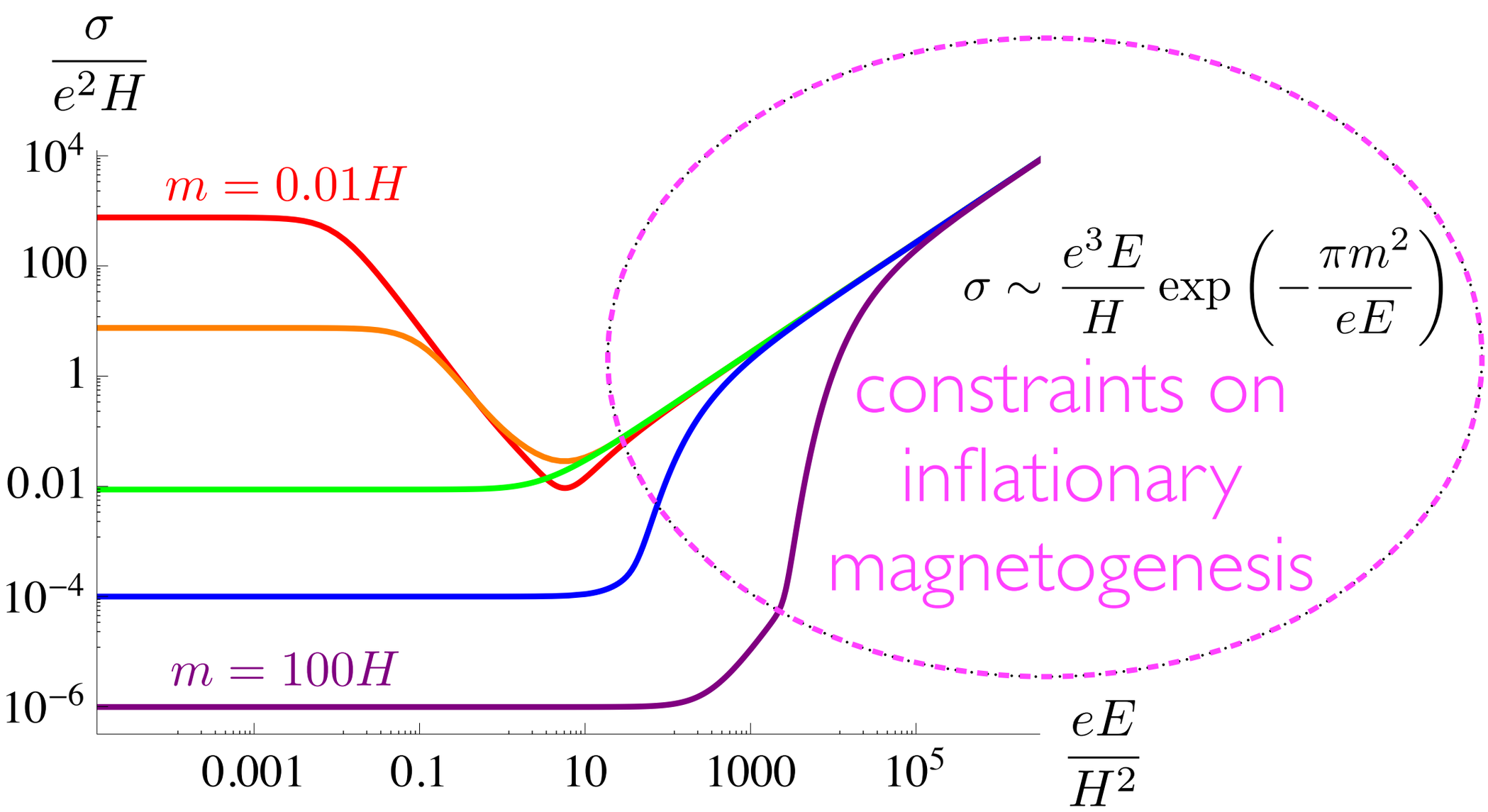
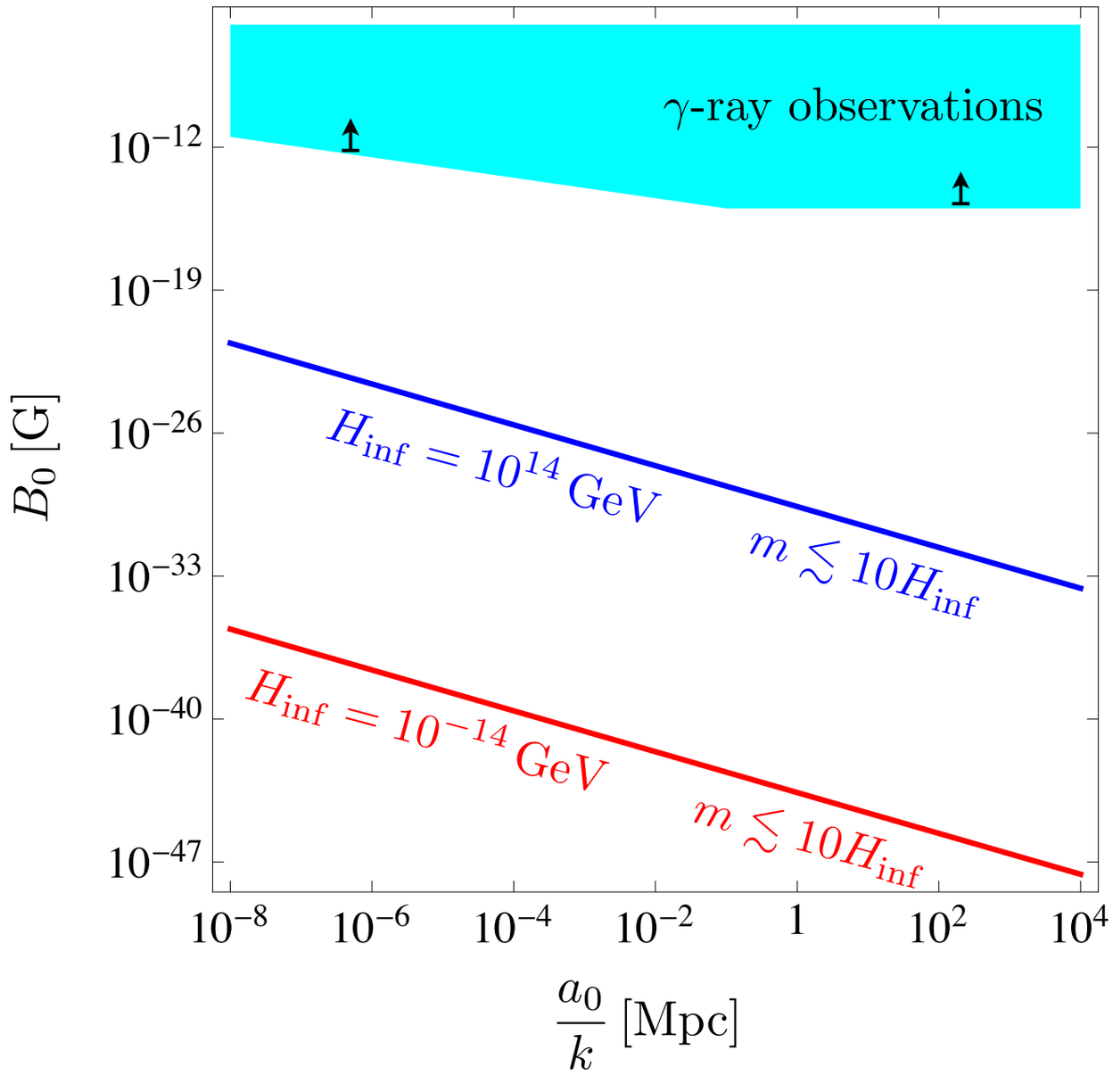


Schwinger production of fields with charge e and mass m

SCHWINGER CONSTRAINT ON MAGNETIC FIELD

$$|B_0| \lesssim 10^{-28}\mathrm{G} \left(\frac{k}{a_0}\,\mathrm{Mpc}\right) \left(\frac{H_{\rm inf}}{M_p}\right)^{1/2} \left(\frac{\sqrt{4\pi\alpha}}{e}\right)^3 I_{\rm end}^2 \exp\left\{W\left(10^{-3}\,\frac{e^2}{4\pi\alpha}\,\frac{1}{sI_{\rm end}^2}\,\frac{m^2}{H_{\rm inf}^2}\right)\right\}$$



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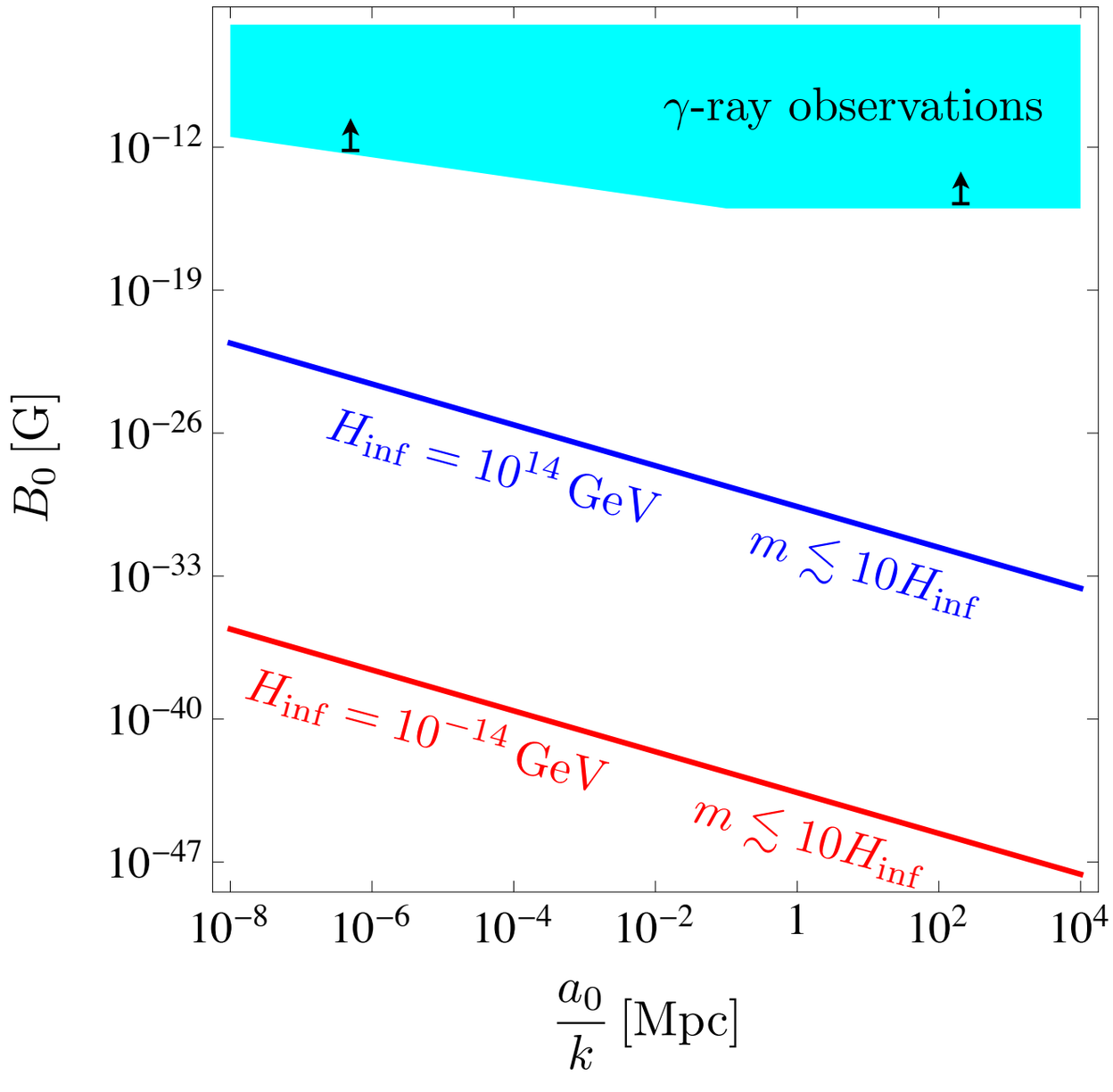

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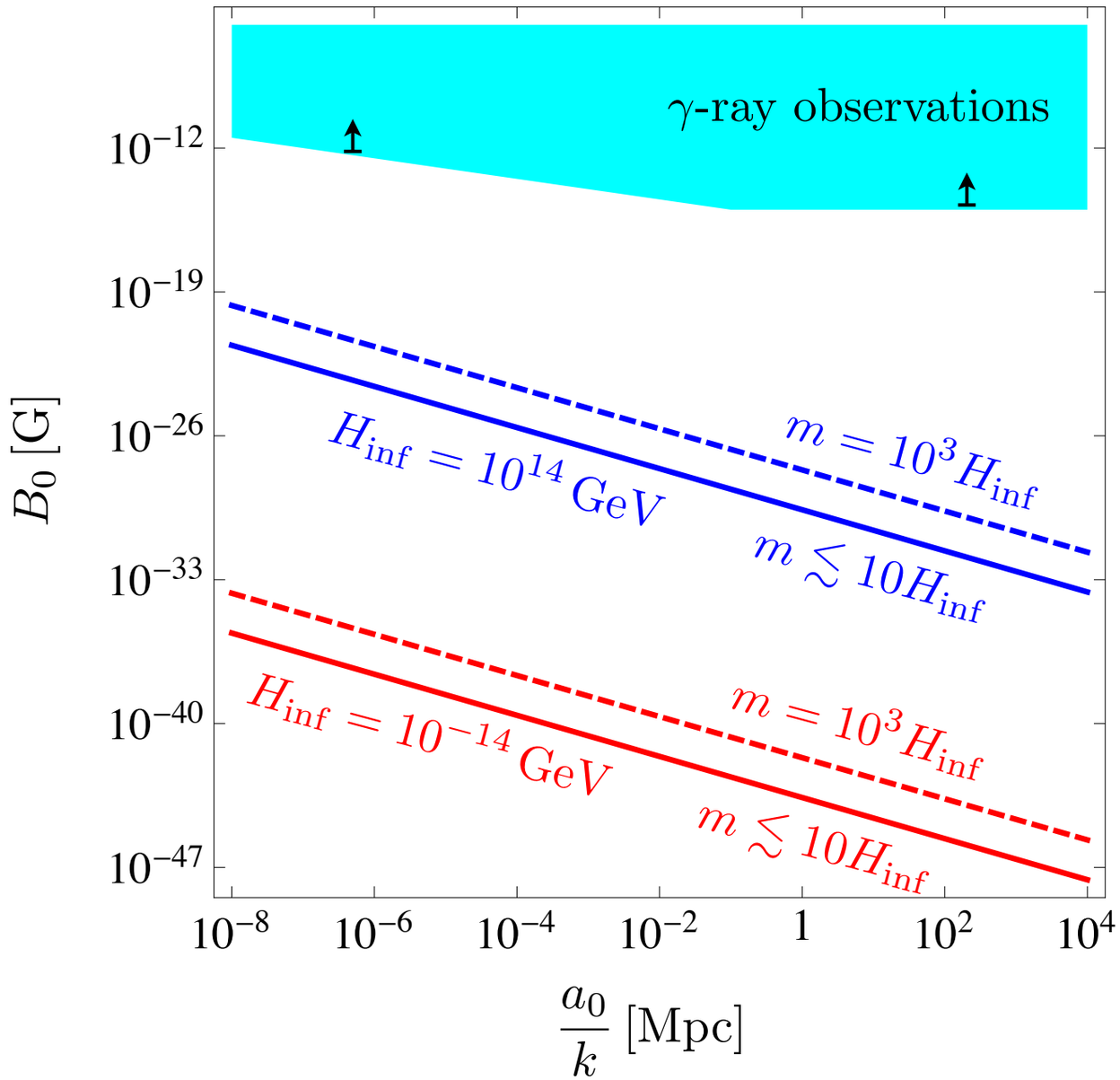

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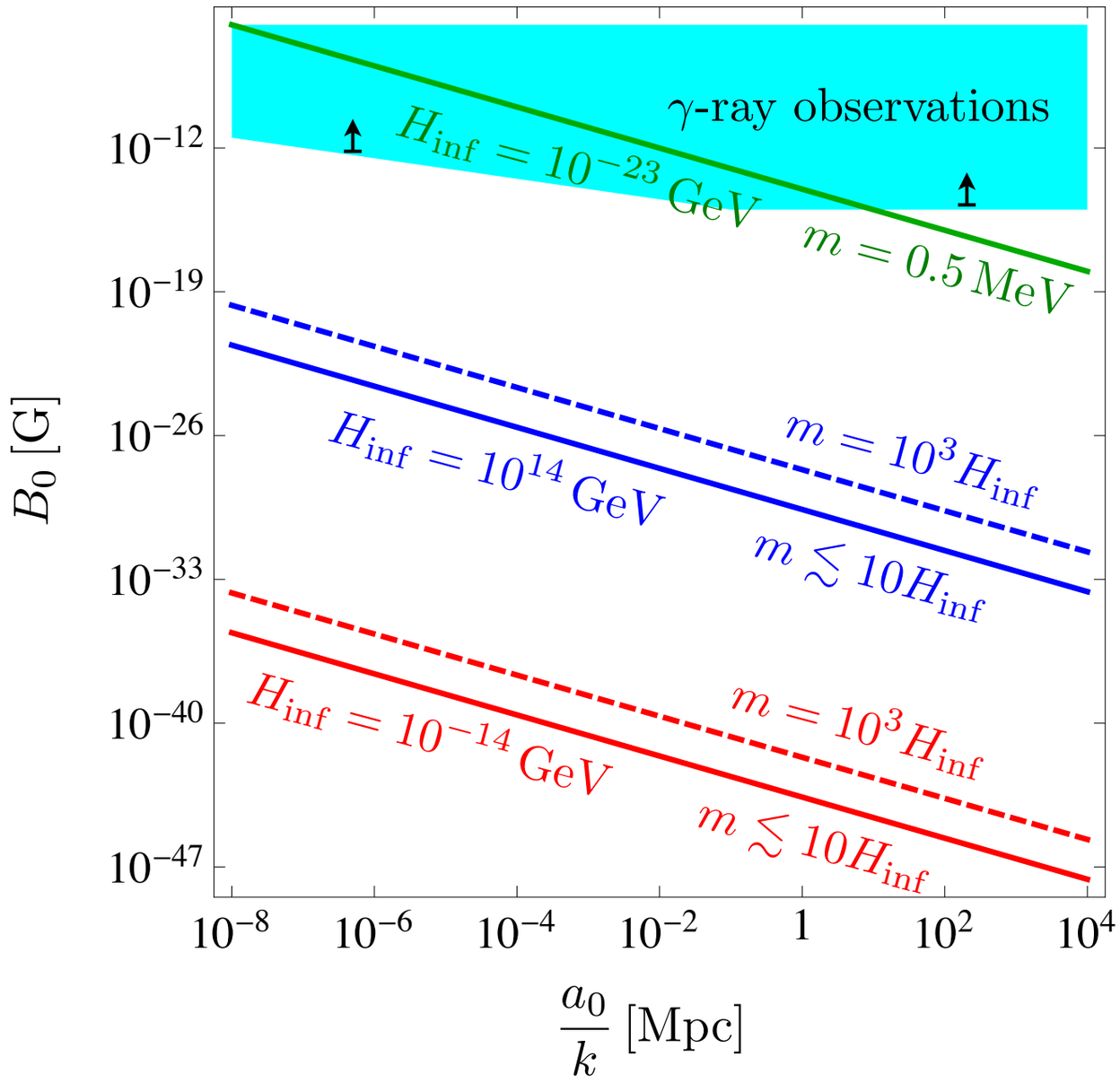

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Schwinger constraint on magnetic fields from the inflationary epoch:

$$B \lesssim 10^{-30}\mathrm{G}$$ on Mpc scales

unless...

- all charged fields have heavy mass ($\gg H_{inf}$)
- all charged fields have tiny charges
- charged fields do not exist in the action during inflation

Schwinger constraint on magnetic fields from the inflationary epoch:

$$B \lesssim 10^{-30}\mathrm{G}$$ on Mpc scales

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- all charged fields have heavy mass ($\gg H_{inf}$)
- all charged fields have tiny charges
- charged fields do not exist in the action during inflation
- magnetogenesis after inflation

POST-INFLATIONARY MAGNETOGENESIS

TK '14

- Magnetic fields can be generated up until reheating.
- Avoids electric backreaction, strong couplings, spoiling density pert.
- May also evade the Schwinger constraint.

SUMMARY

- Schwinger effect imposes $B < 10^{-30}\mathrm{G}$ for inflationary I^2FF models in the presence of fields carrying elementary charge and $m \lesssim H_{inf}$.

- Post-inflationary magentogenesis may evade the Schwinger constraint.

- Further investigation of cosmological magnetic fields may provide new insights into the very early universe!