Populating a dark sector from neutrinos after BBN, H_0 & S8

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8/30/2023

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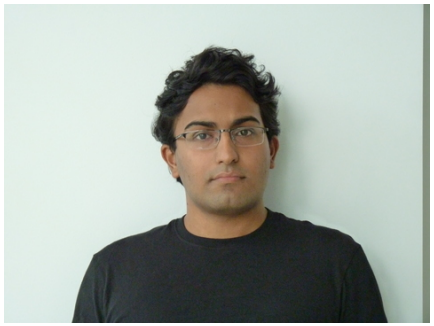


Eashwar Sivarajan
Boston - grad student

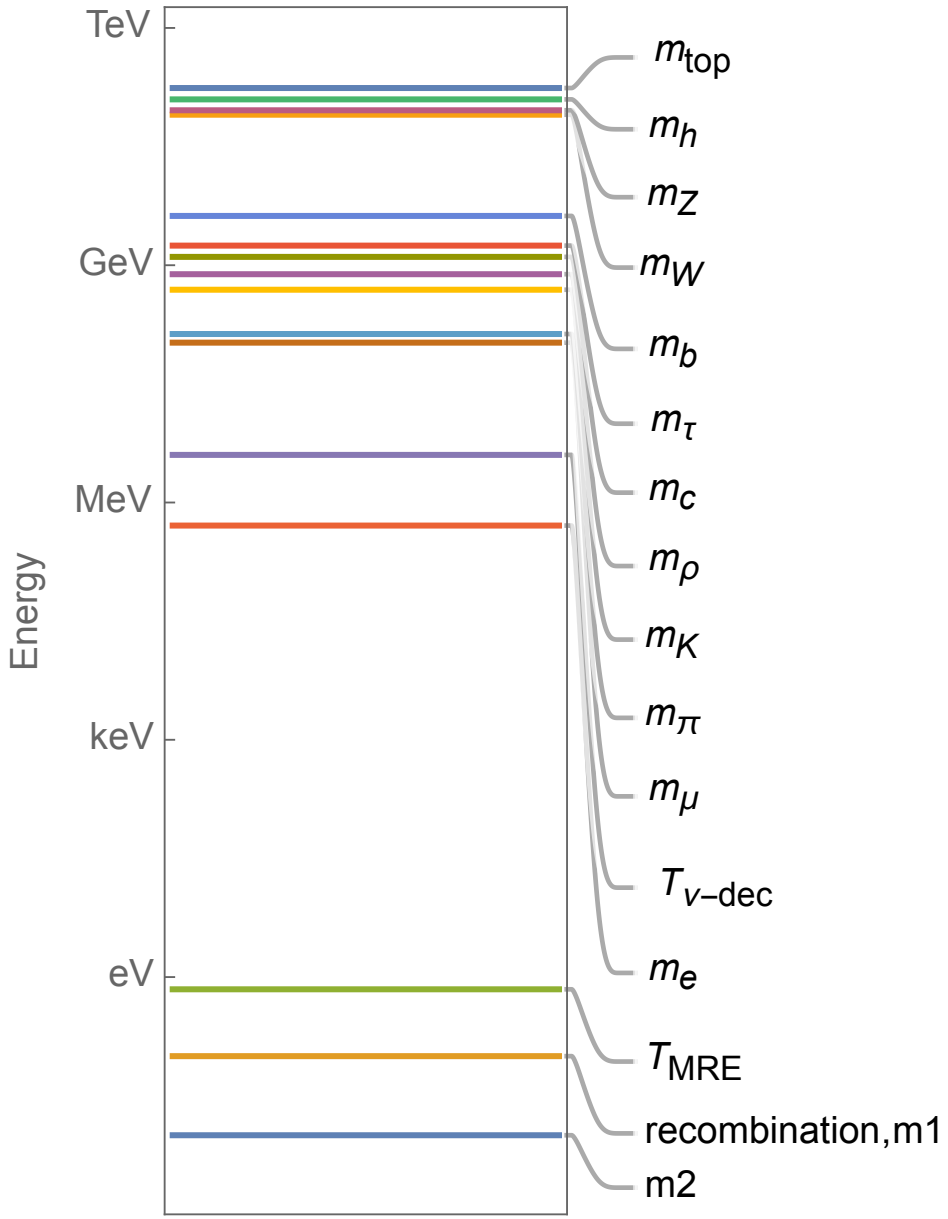
Neal Weiner
NYU faculty

Outline

- the ΛCDM “desert”
- populating a dark sector from the neutrinos
- applications:
  Neff with a step, H_0 and S8, neutrino cooling and BBN
- summary

The ΛCDM desert

empty?



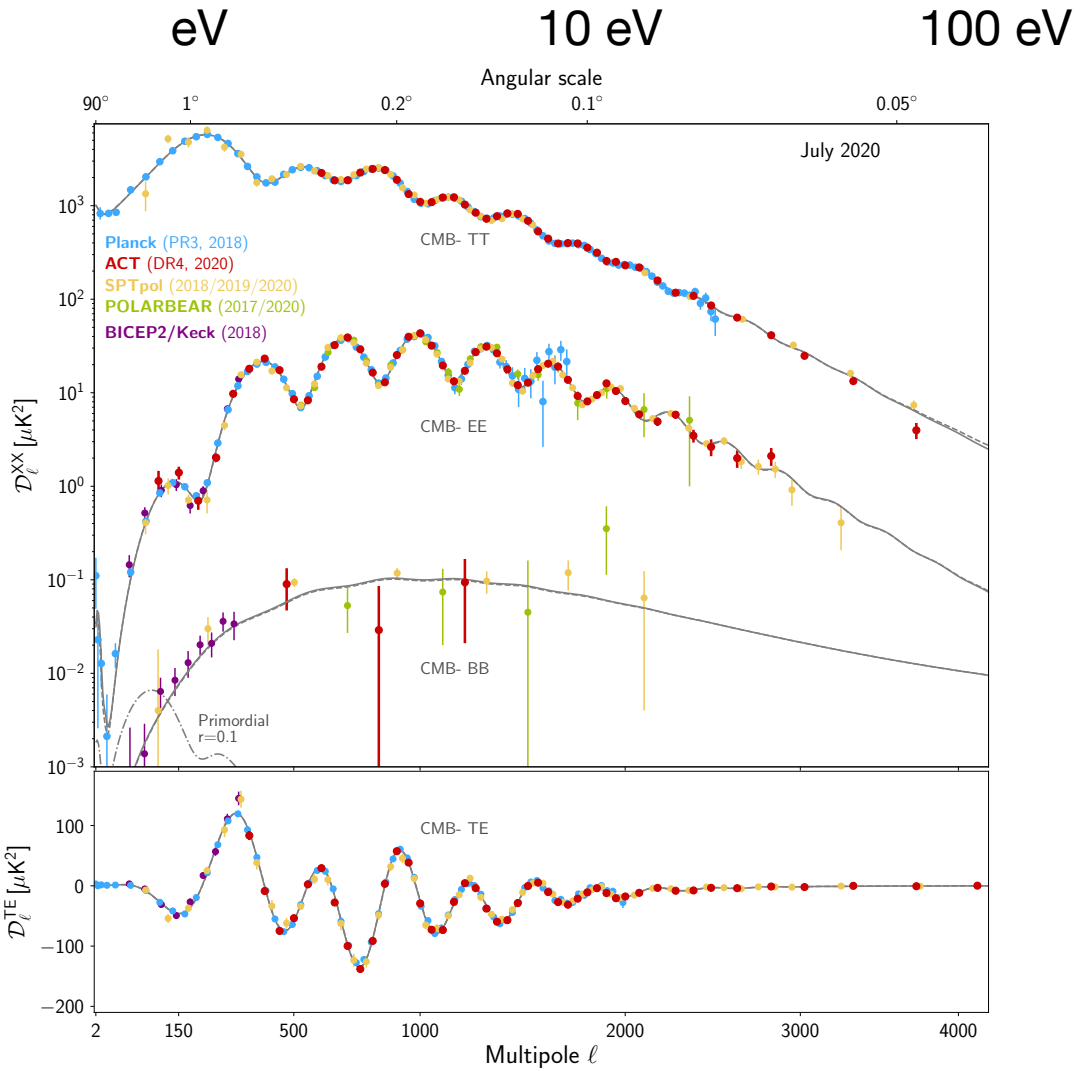
What's in the eV-MeV desert?

What's in the eV-MeV desert?

data!

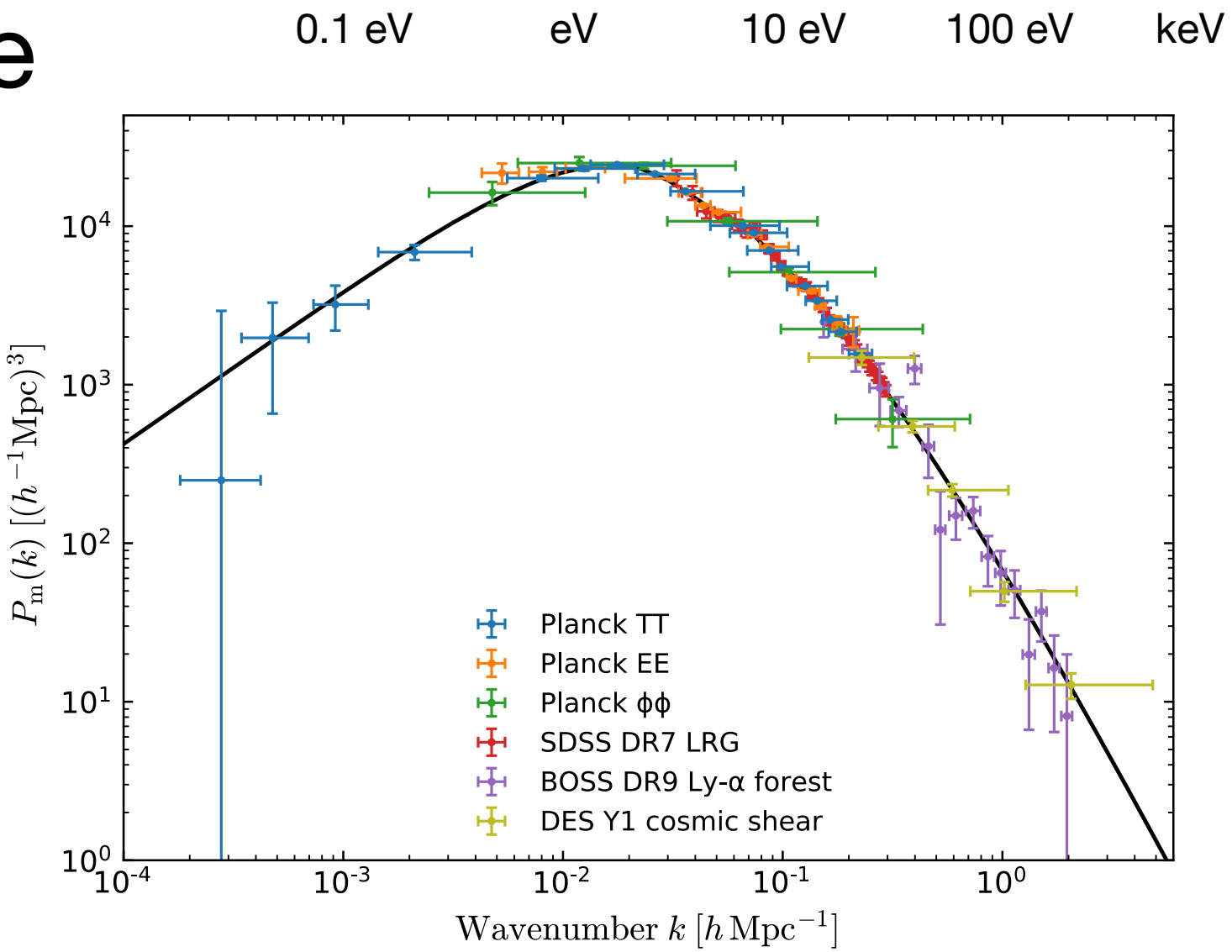
data in the eV-MeV desert

CMB



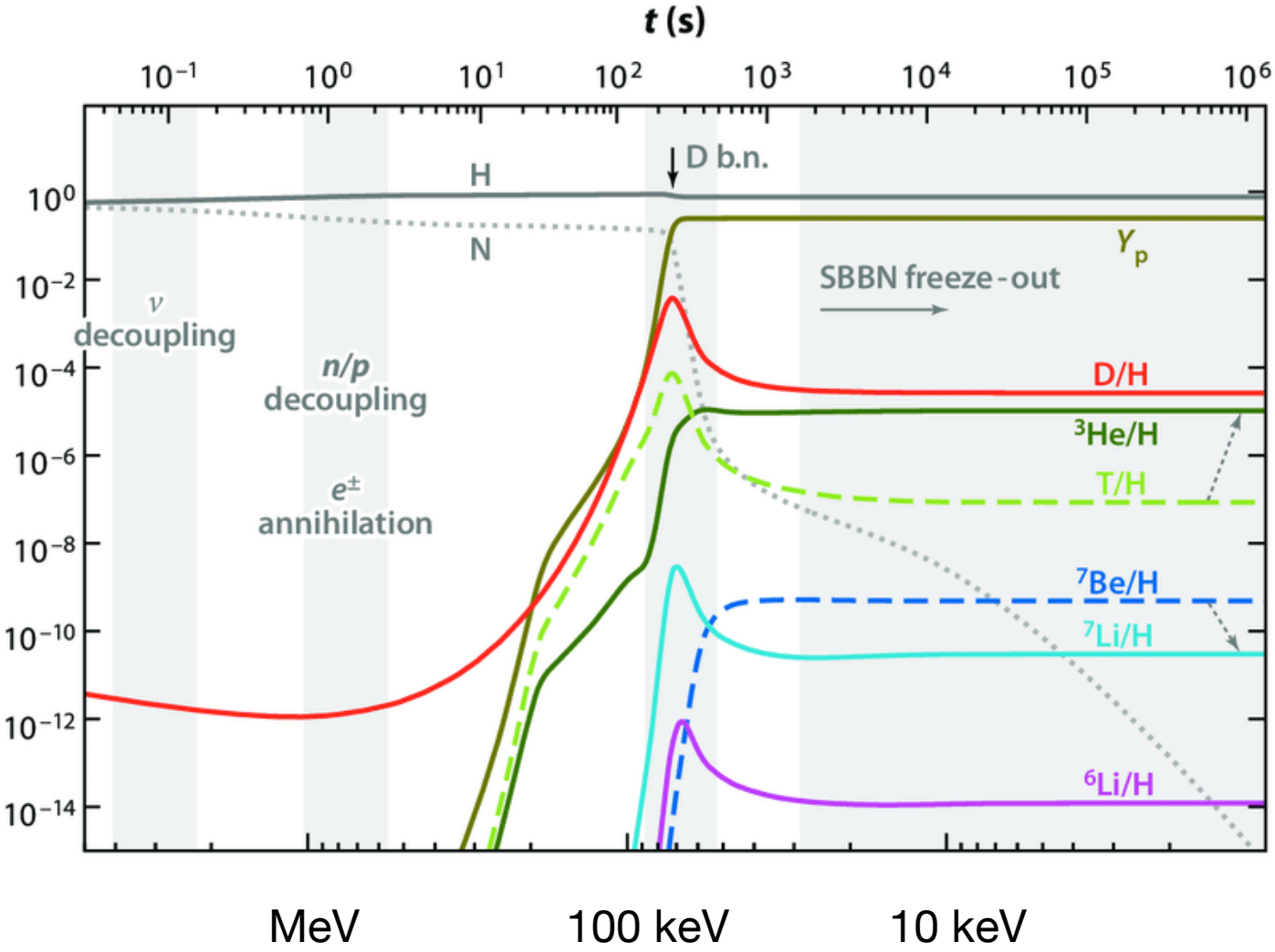
data in the eV-MeV desert

Large Scale Structure



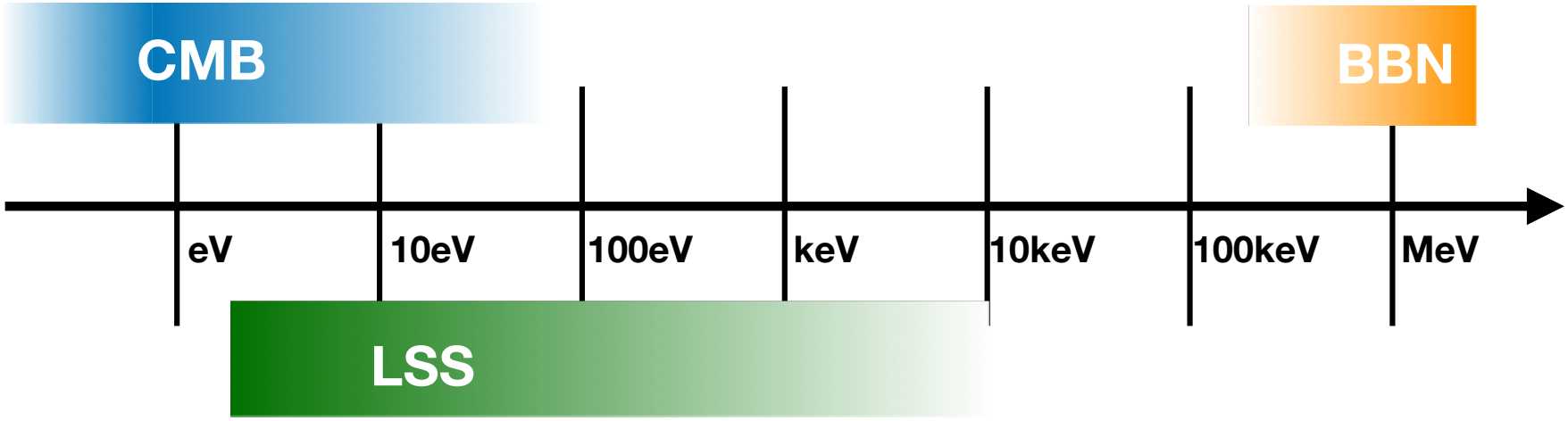
data in the eV-MeV desert?

BBN



This is the era of the experimental exploration of the desert

today: WMAP, SDSS, Planck, BOSS, ACT, SPT,…



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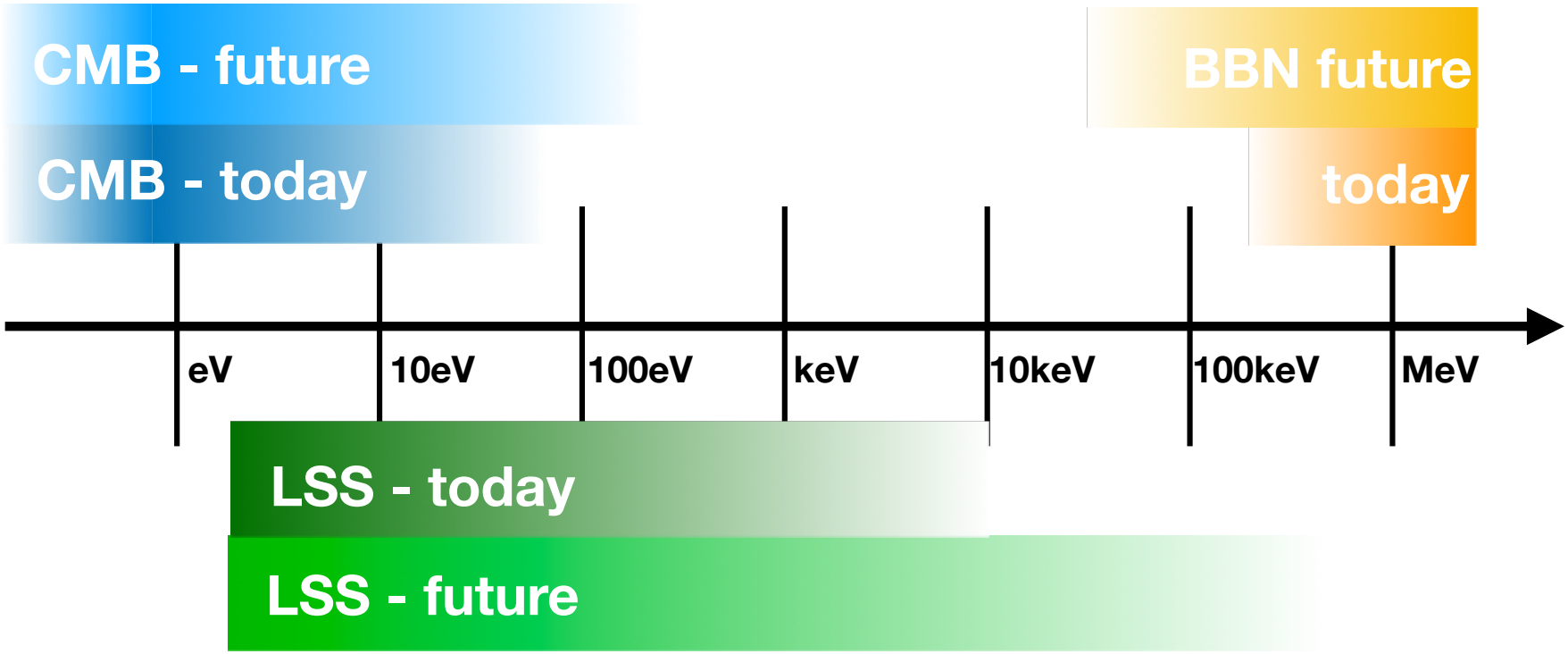


future: Rubin, EUCLID, Roman, Simon's O, CMB-S4, …

What else is in the eV-MeV desert?

data - anomalies

What else is in the eV-MeV desert?

data - anomalies

H_0 Hubble Tension

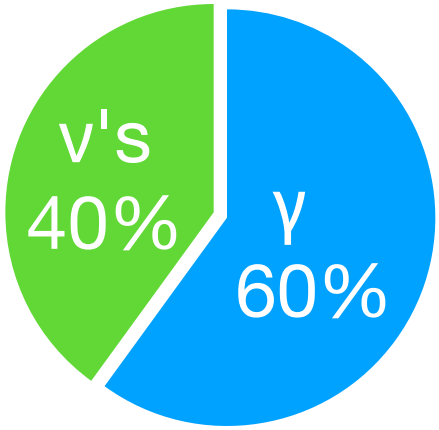
S8 LSS Tension

D/H Deuterium abundance

- The desert provides a great opportunity to probe and discover new physics thresholds between eV-MeV scales

- What new physics might we expect to see?

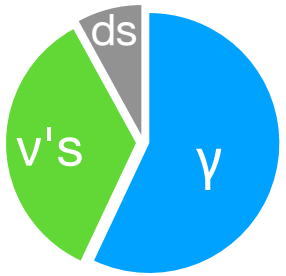
The universe is radiation dominated for T > eV



Most natural expectation:

a dark sector with radiation N_{eff}

Want the extra radiation to have observable consequences (e.g. for H_0) but not ruled out -> $N_{eff} \sim 1$.

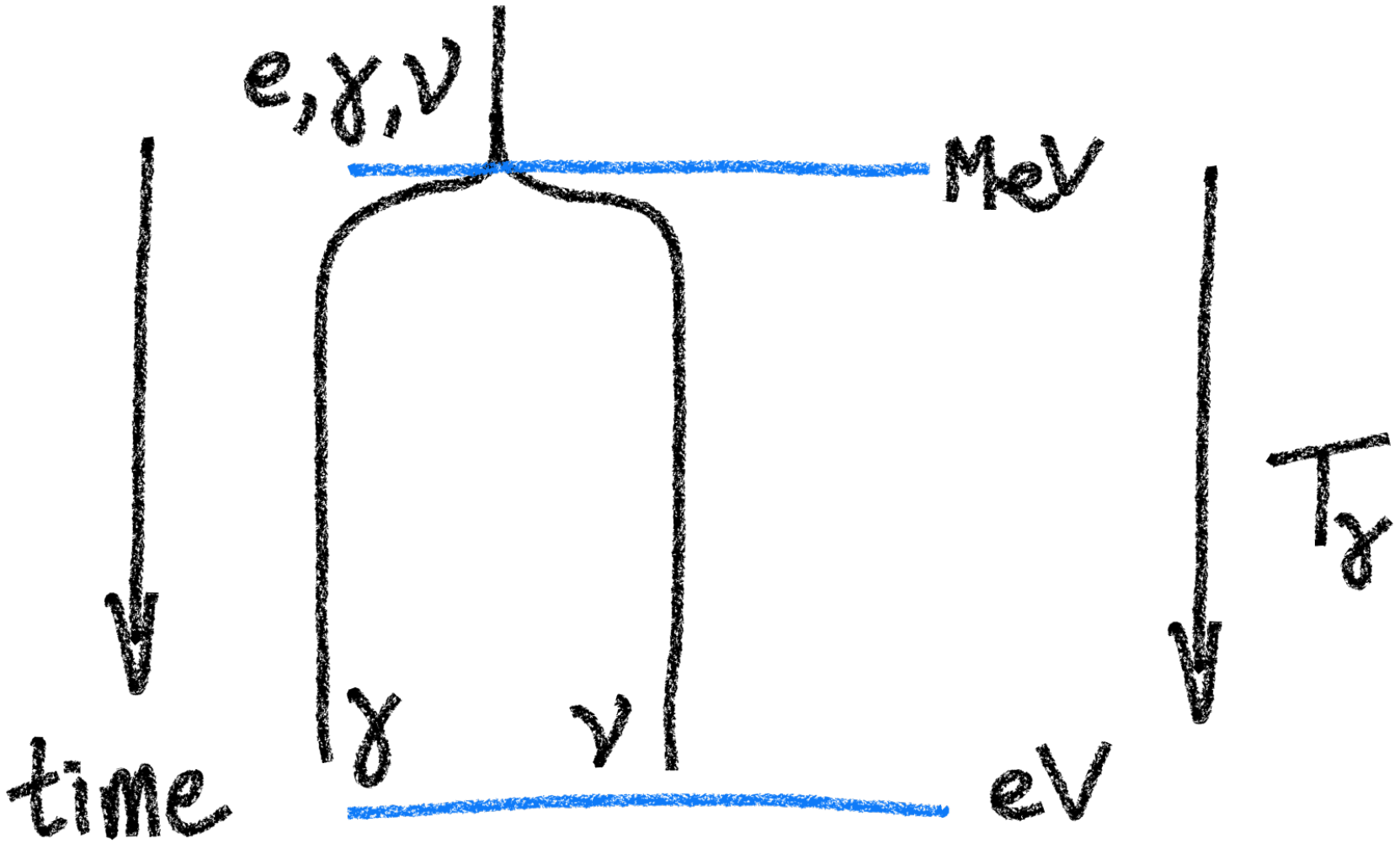


How can this be natural?

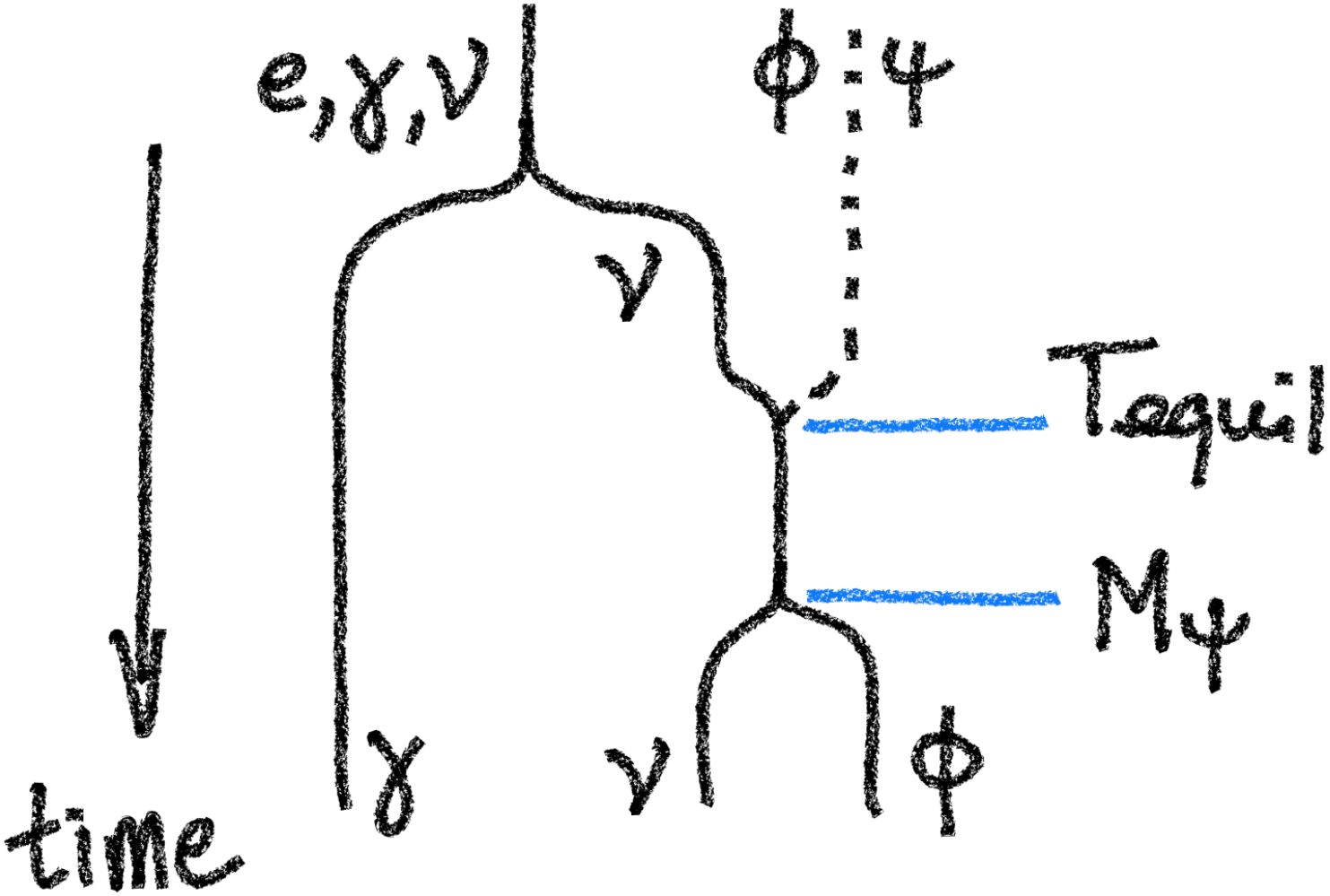
Idea: populate the dark sector by thermalizing with the neutrinos after neutrino decoupling

A.Berlin, N.Blinov 1807.04282
D.Aloni, M.Joseph,M.Schmaltz,N.Weiner 2301.10792

ΛCDM cosmological history



Alternative cosmological history



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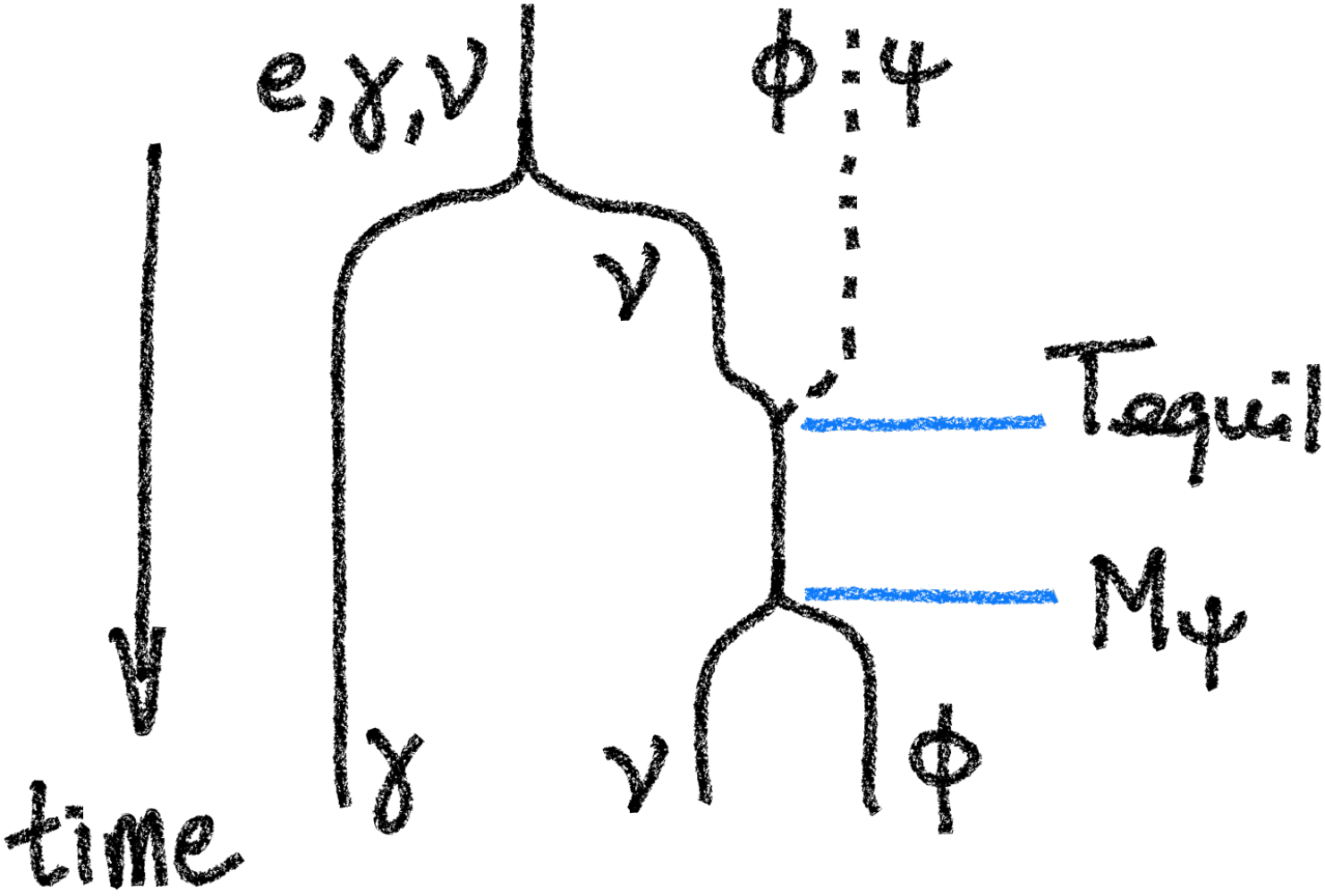
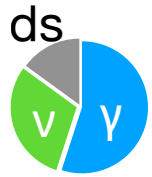




A very simple model

(Aloni,Joseph,Schmaltz,Weiner 2301.10792)

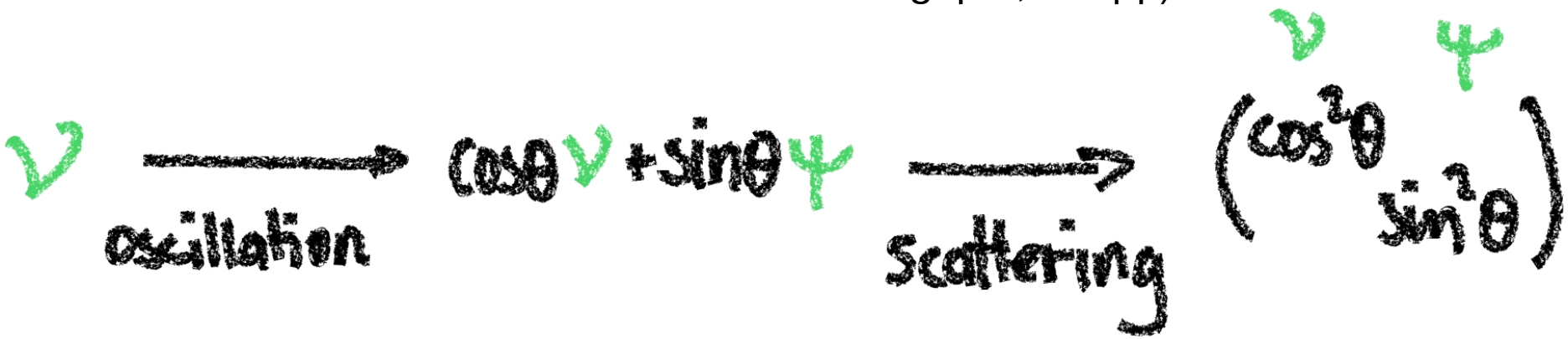
$$\mathcal{L} \sim m_\psi \psi\psi + m_{mix} \nu\psi + \lambda \phi \psi\psi$$

dark fermion mass

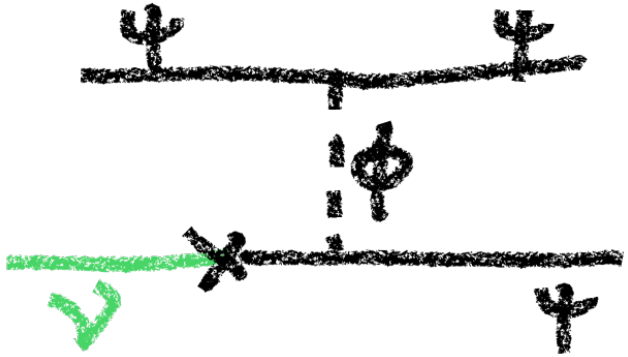
mixing with ν

Thermalizing through the neutrino portal

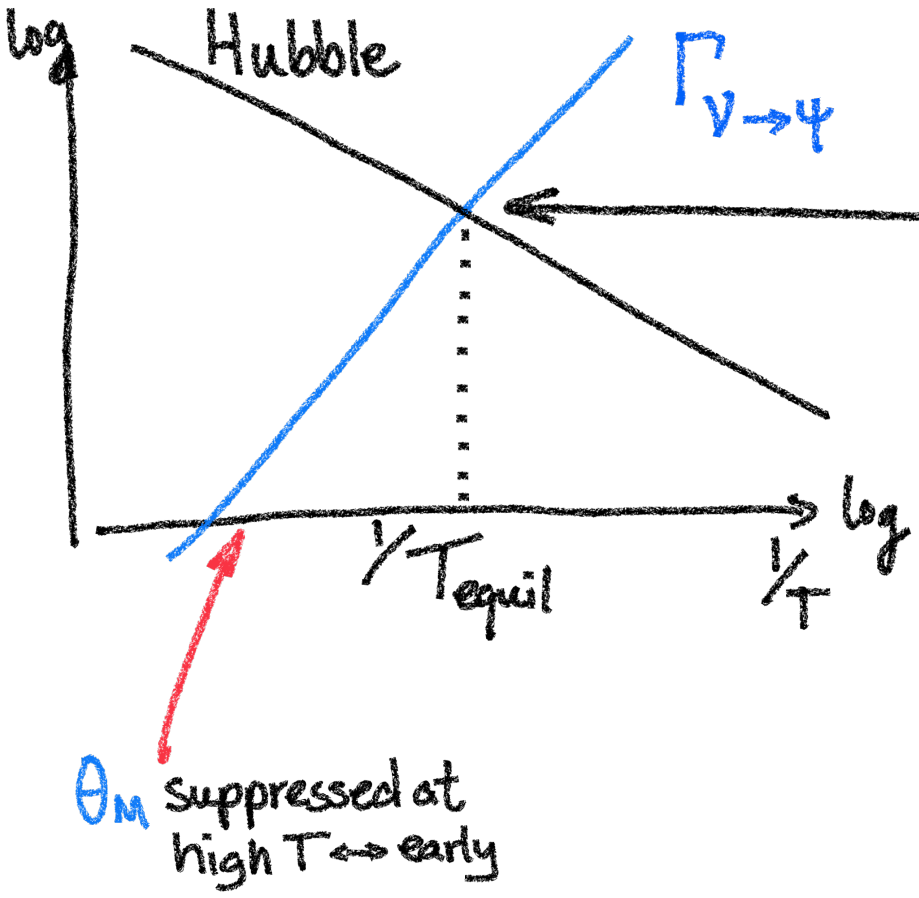
(c.f. Dodelson-Widrow with secret interactions B.Dasgupta,J.Kopp)



$$\Gamma_{\nu \to \psi} = \frac{1}{4} \sin^2\theta_m \, \Gamma_{\psi\,\text{scattering}}$$



Thermalizing through the neutrino portal

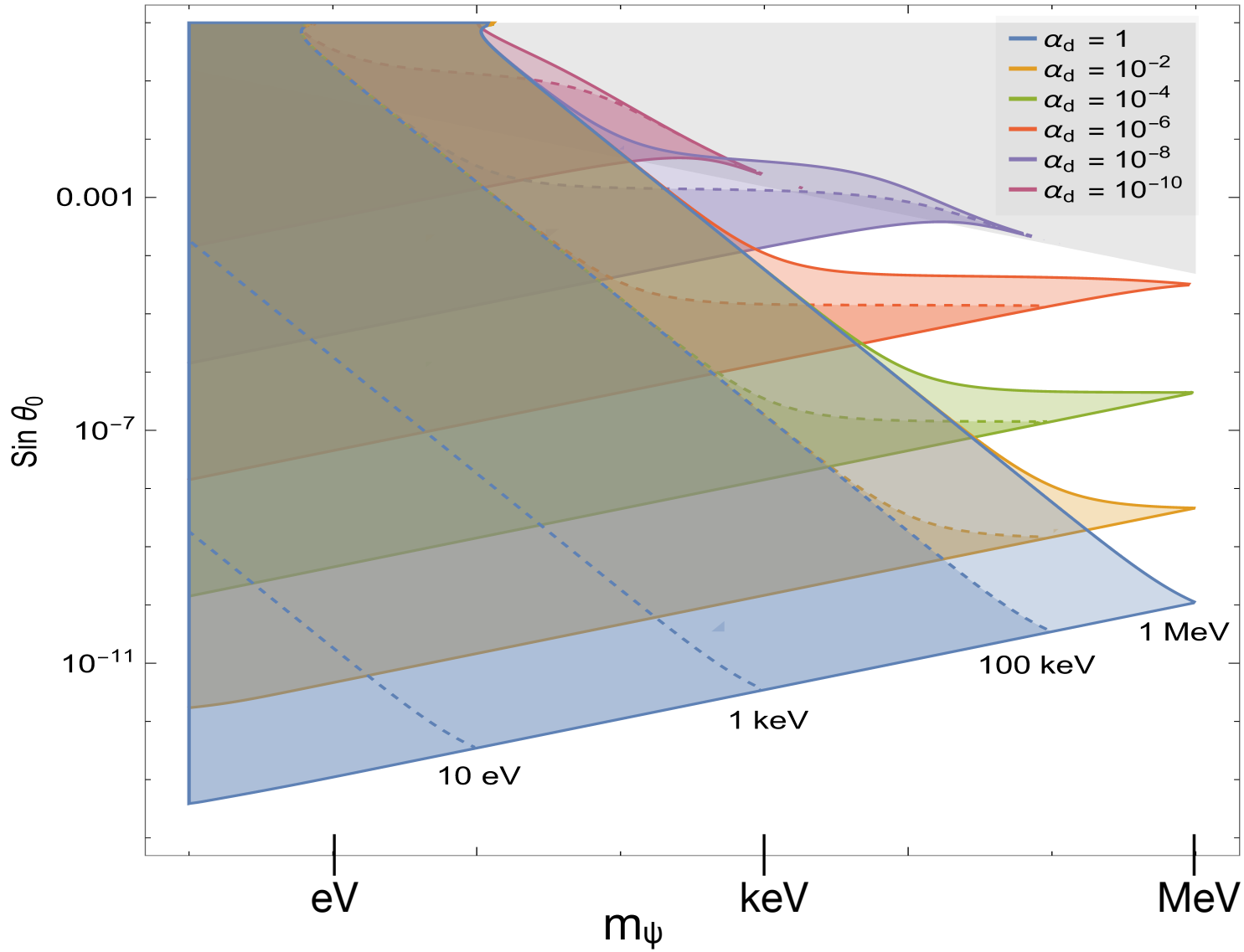


$$\Gamma_{\nu\to\psi} = \frac{1}{4}\sin^2\theta_m\,\Gamma_{\psi\,\text{scattering}} = H$$

$$T_{equil} \approx m_\psi \left(\frac{\theta_0^2 M_{pl}}{m_\psi}\right)^{1/5}$$

Equilibration is generic and occurs at $T_{equil} \approx m_\psi \left(\frac{\theta_0^2 M_{pl}}{m_\psi}\right)^{1/5}$

Aloni,Joseph,Schmaltz,Weiner 2301.10792



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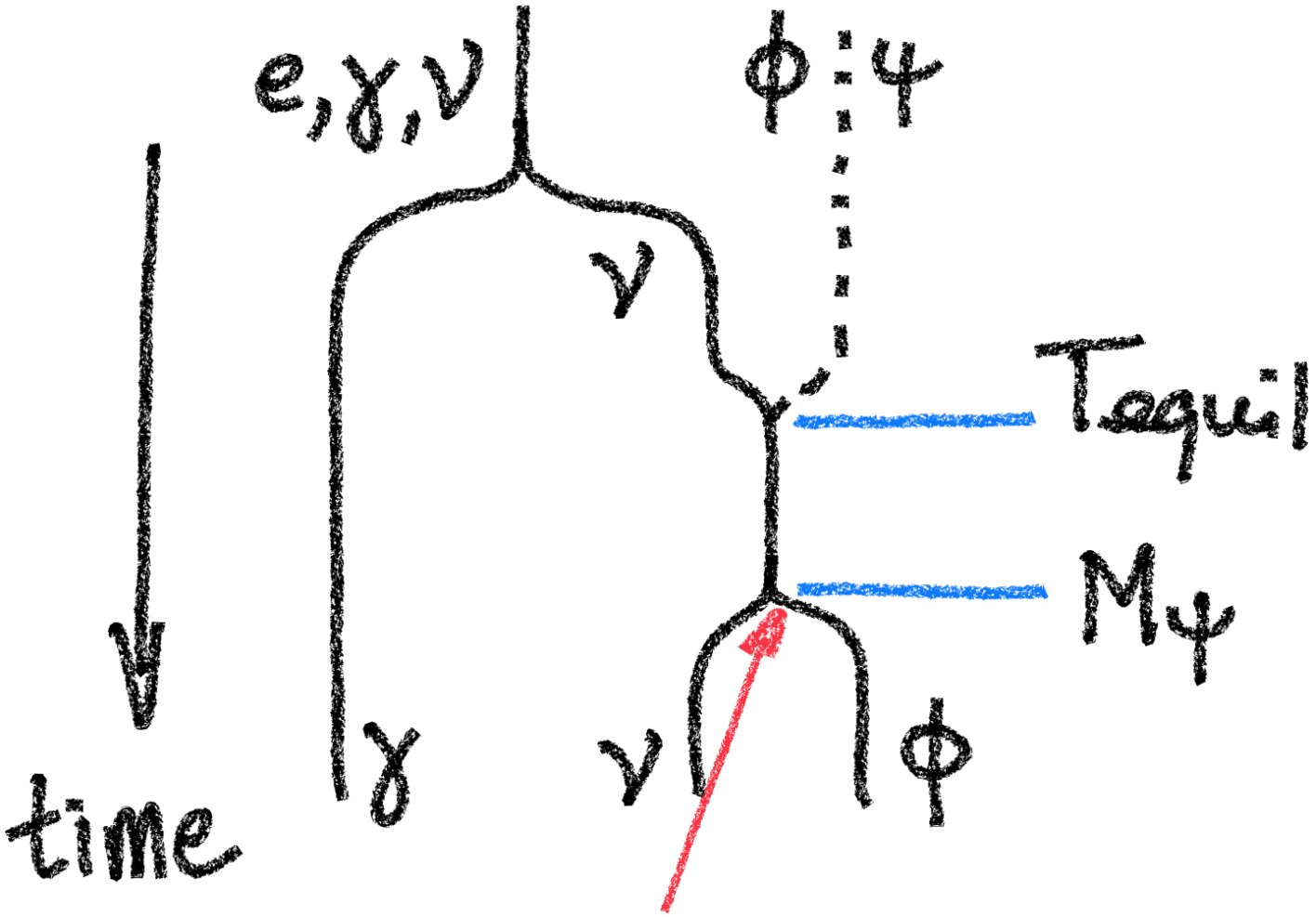


Recap:

- Can generically thermalize a dark radiation sector below MeV via neutrino portal

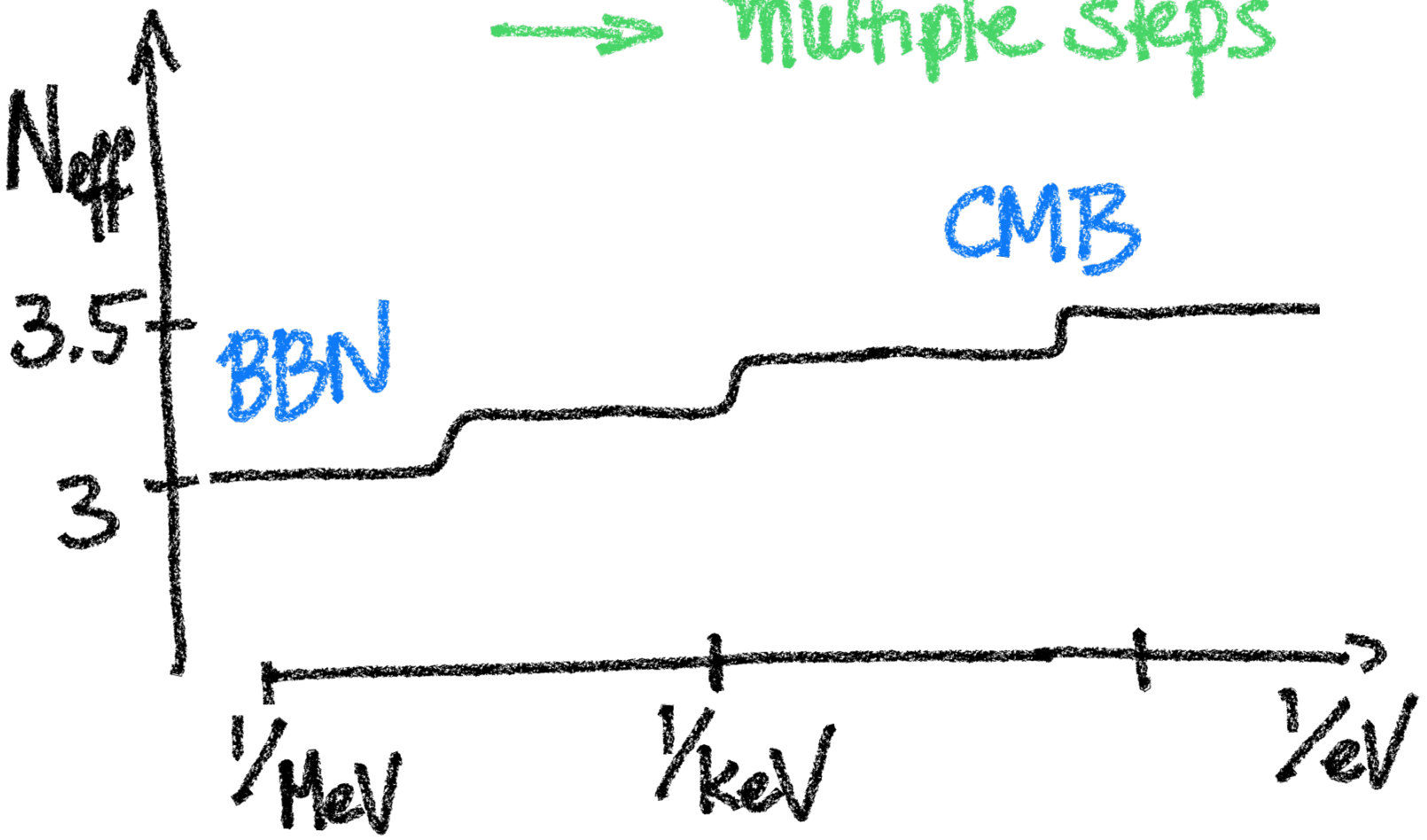
  $\longrightarrow$ $N_{eff}(BBN) = 3$

- massive particles in dark sector annihilate and produce a "step" in Neff

  $\longrightarrow$ $N_{eff}(CMB) = 3 + \Delta N_{eff}$

Multiple massive particles in dark sector

→ multiple steps



Applications – Signatures

- a step in N_{eff} reduces the Hubble tension H_0

Aloni,Berlin,Joseph,Schmaltz,Weiner
2111.00014

- dark matter - dark radiation interaction with a step improves S_8

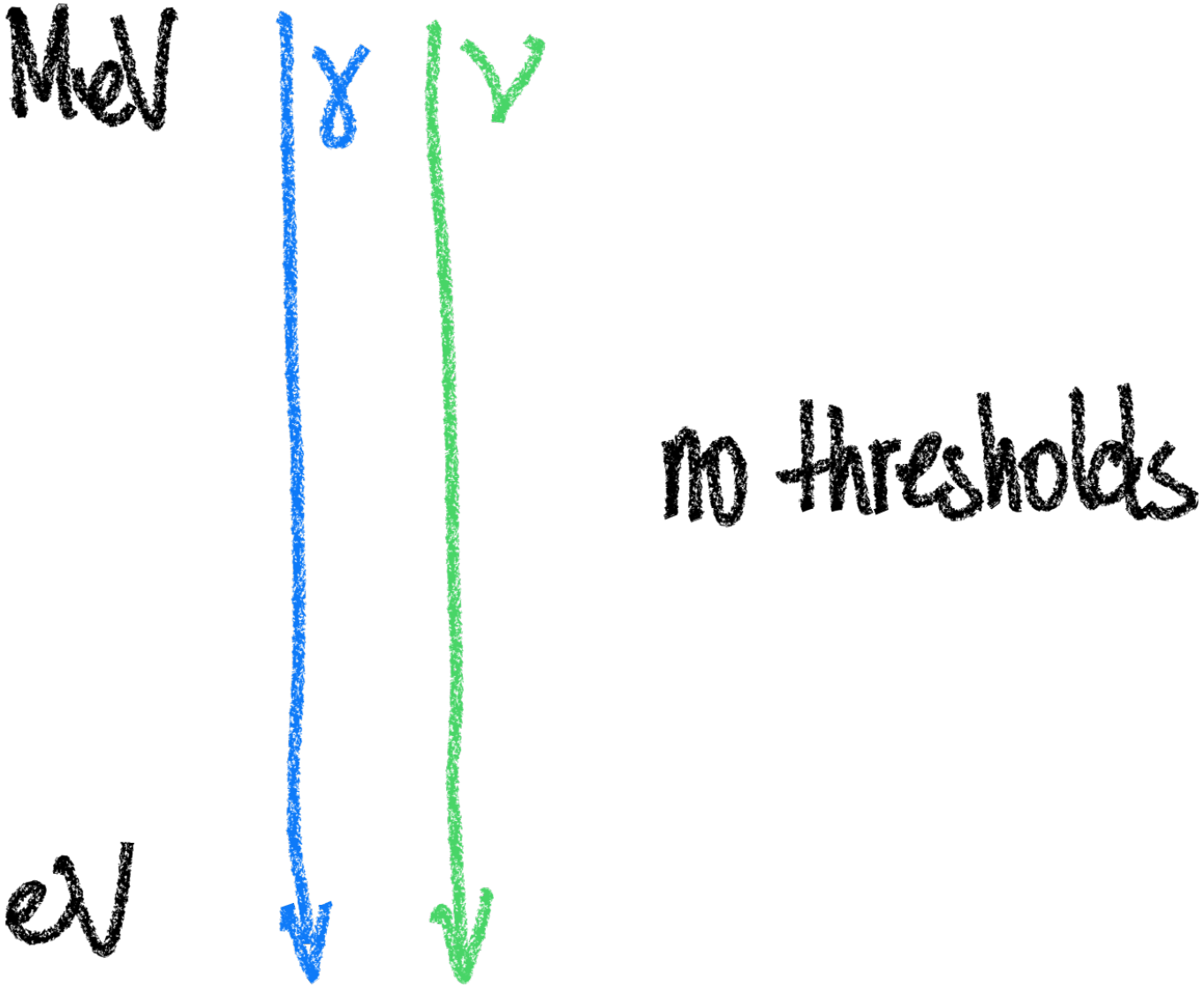
Joseph,Aloni,Schmaltz,Sivarajan,Weiner
2207.03500

- a step during BBN ~ 100keV modifies D/H

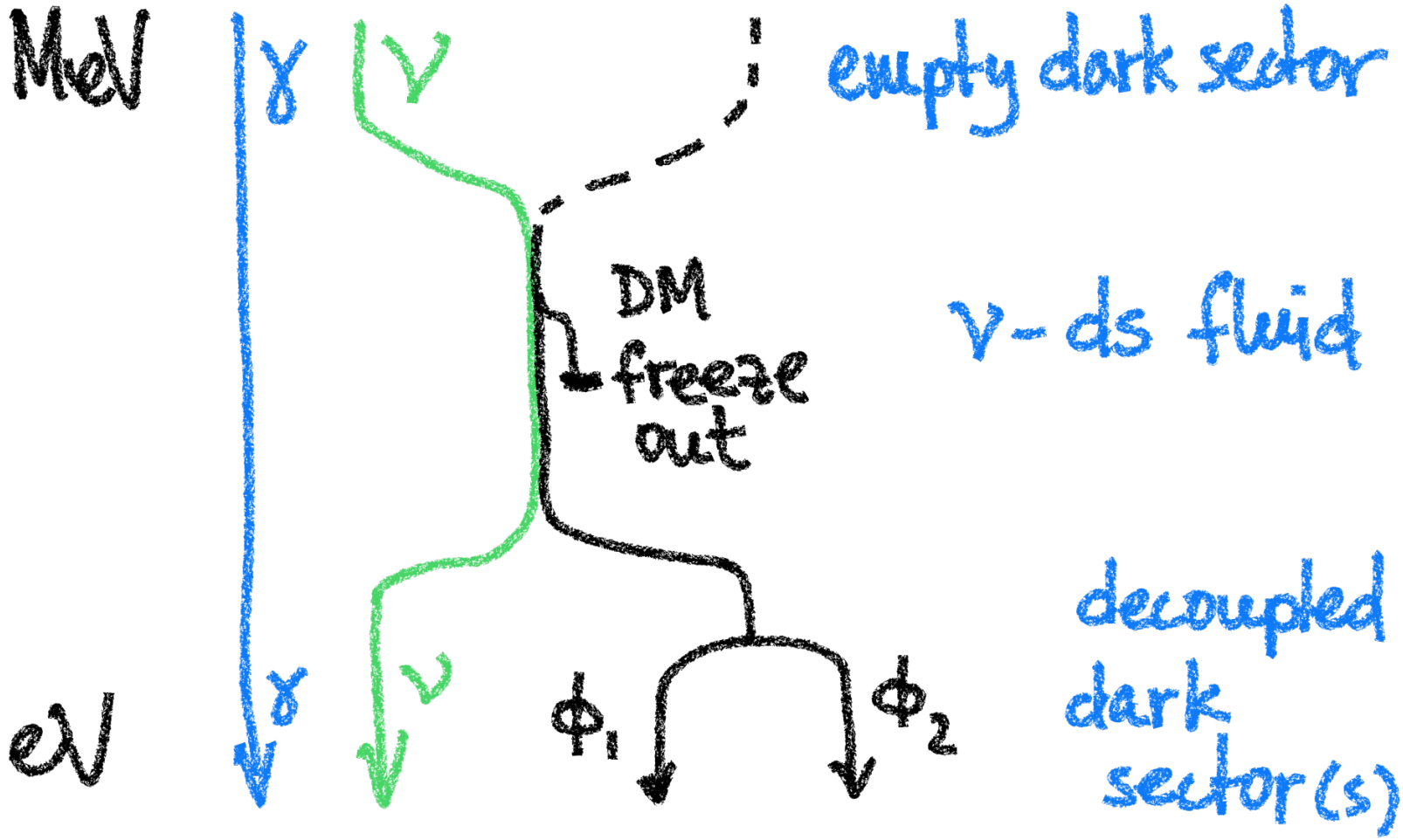
Giovanetti,Schmaltz,Weiner
in progress

Summary

ΛCDM desert



Desert populated through the ν-portal



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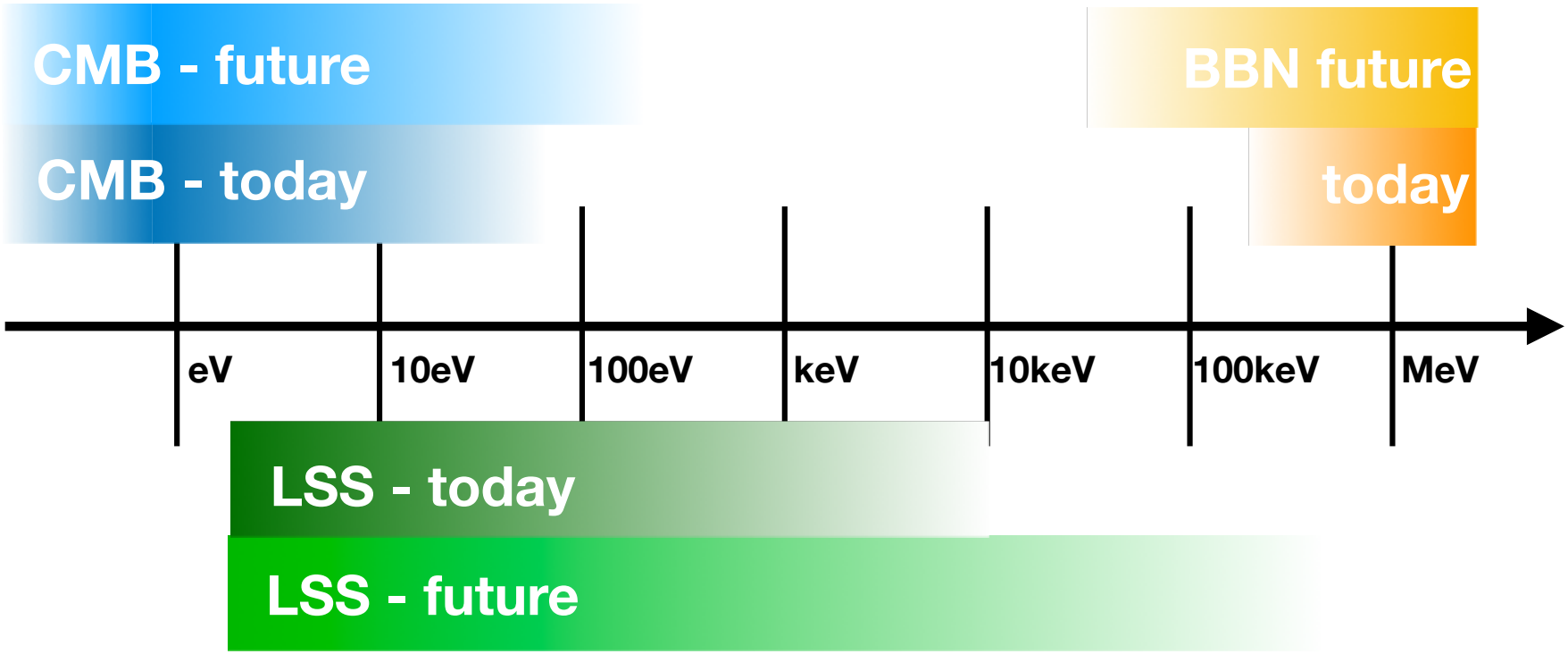


future: Rubin, EUCLID, Roman, Simon's O, CMB-S4, …

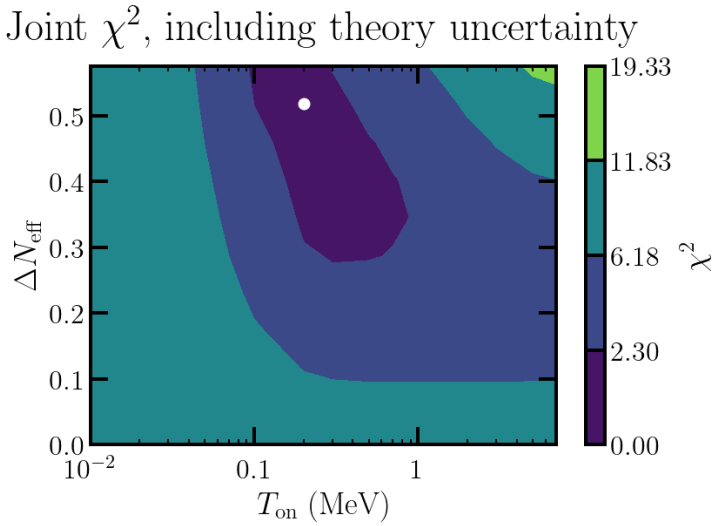
Back up!

aside on BBN

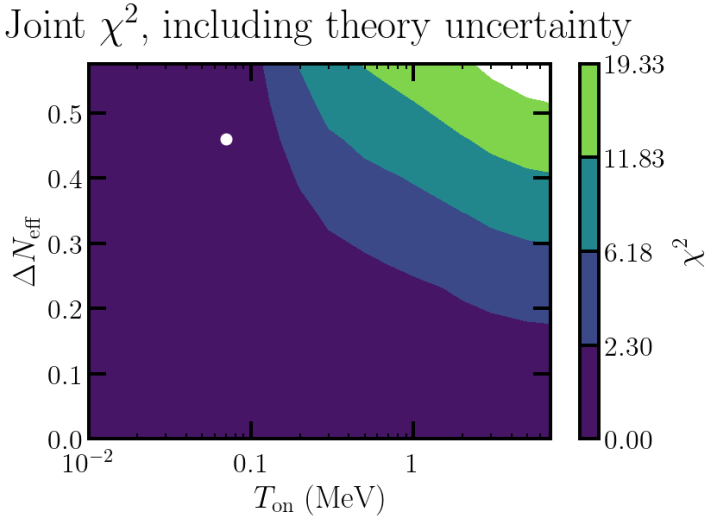
- Two public codes: PRIMAT and PArthENoPE
- different input values for d+d->n+^{3}He and d+d -> p+^{3}H
- No clear reason to prefer one or the other right now
- New data needed to clarify

Steps in BBN

- If a dark sector equilibrates and goes through a step *before* Deuterium freeze out but after neutrino decoupling, it will affect D and He differently (Berlin, Blinov + Li)



PRIMAT



PArthENoPE

Giovanetti, Schmaltz, Weiner in progress