Non-Cold Dark Matter from Primordial Black Hole Evaporation

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In collaboration with
I. Baldes, D. C. Hooper, L. Lopez-Honorez
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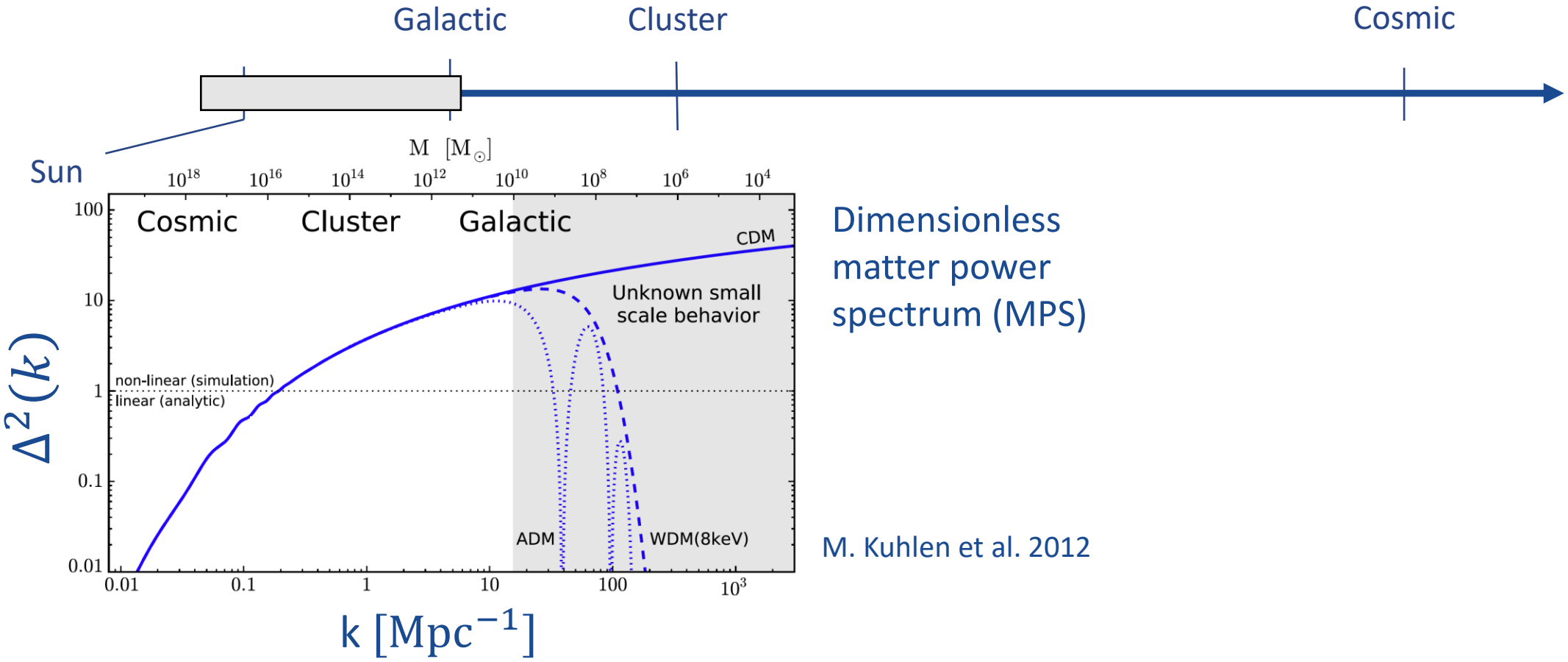
Non-Cold Dark Matter

Dark matter is seed of structure formation



Dimensionless matter power spectrum (MPS)

M. Kuhlen et al. 2012

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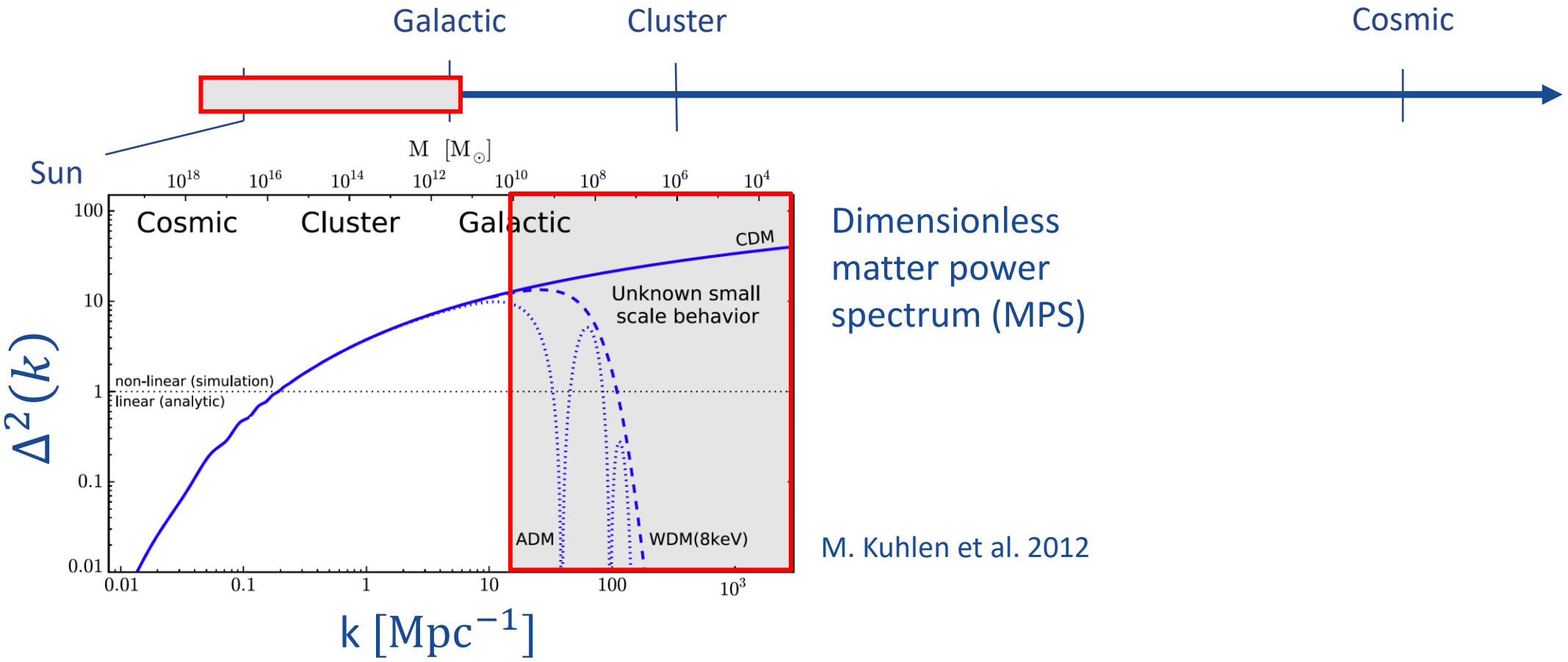

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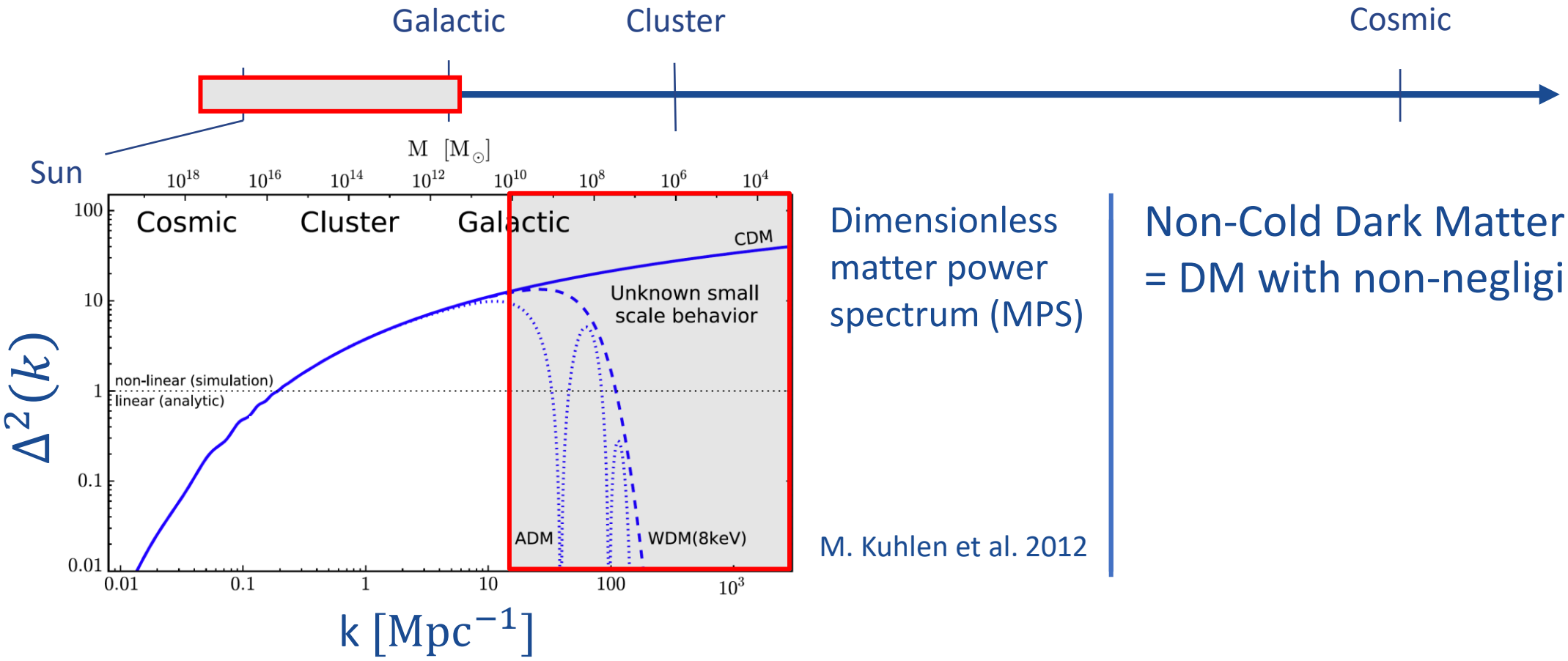

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Non-Cold Dark Matter (NCDM)
= DM with non-negligible velocity

Non-Cold Dark Matter

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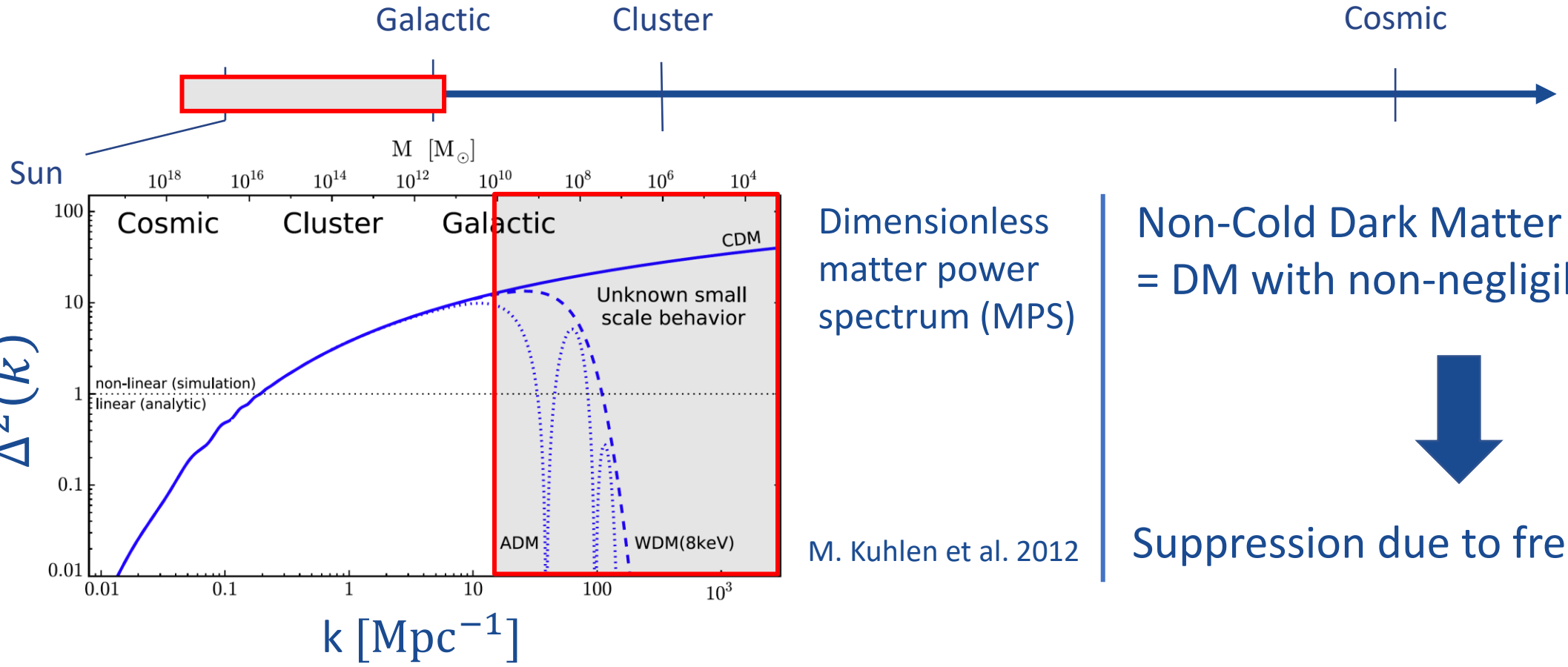

Dimensionless matter power spectrum (MPS)

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Non-Cold Dark Matter (NCDM)
= DM with non-negligible velocity

Suppression due to free-streaming

NCDM from PBH evaporation

NCDM (Spin $\frac{1}{2}$; $m_{NCDM} < T_{BH}$; only Grav. Int.) from PBH evaporation:

See also e.g.:
[Matsas'98, Bell'98,Bauman'07,Fujita'14,Allahverdi'17, Lennon'17,Morrison'17, Hooper'19+, Masina'20, Masina'21,…]

NCDM from PBH evaporation

$M_{BH} \sim 0.1\text{g} - 100\ \text{ton}$
$M_{BH} \sim 10^{-34} - 10^{-25}\ M_{\odot}$

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1. Small BH form early on: $M_{BH} \sim 10^{4} - 10^{13}\ M_{Pl}$

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3. $\rho_{rad} \propto a^{-4}$; $\rho_{PBH} \propto a^{-3}$ if $\beta \equiv \Omega_{PBH}^{initial} > \beta_c$ ➡ Early Matter Dom.

See also e.g.:
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Impact on Matter Power Spectrum

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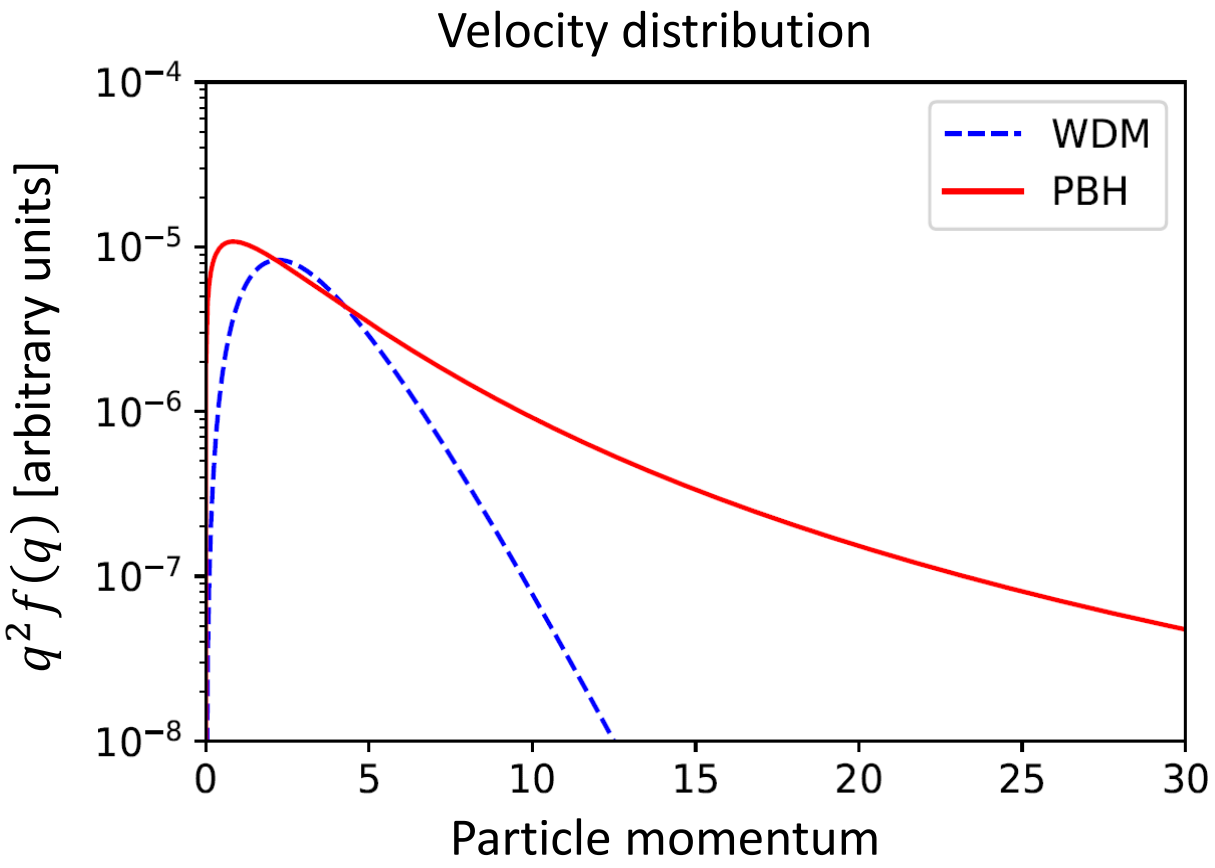
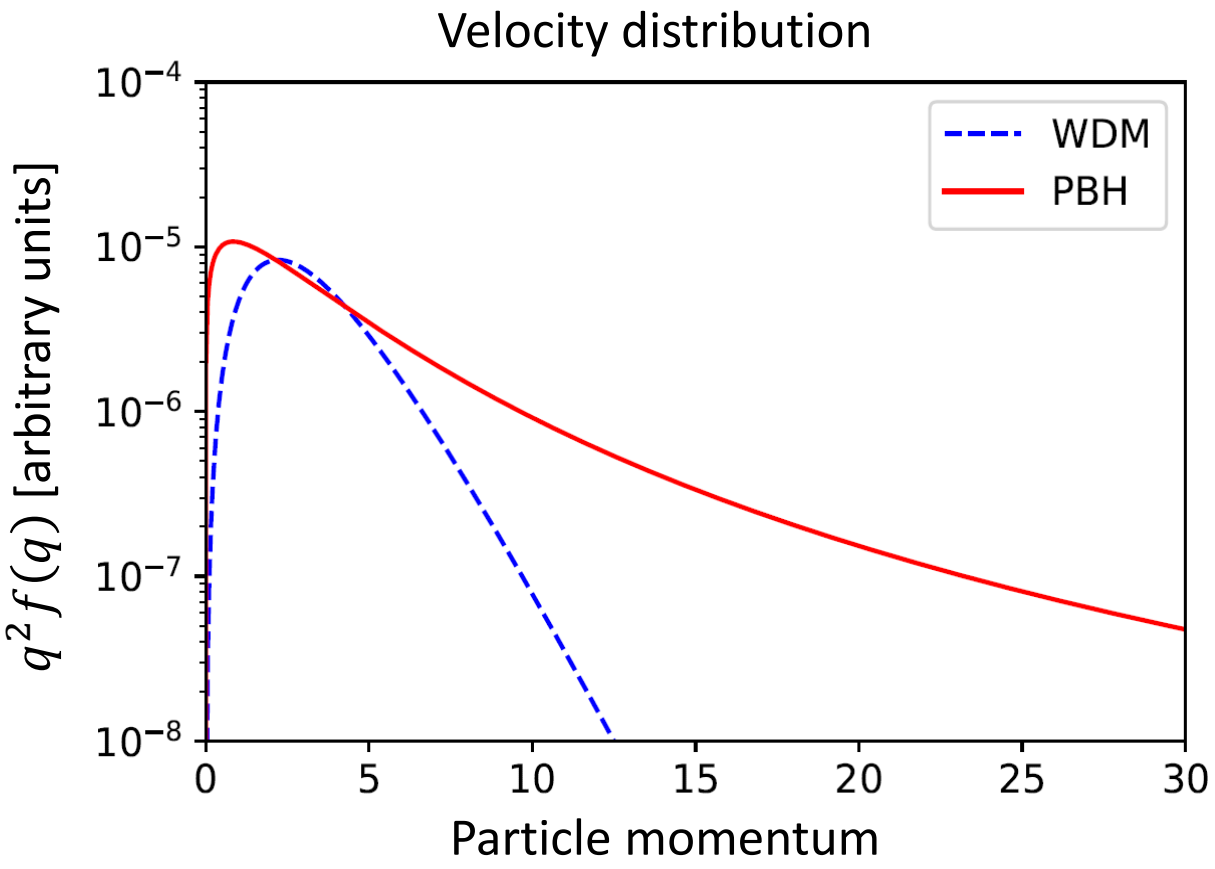
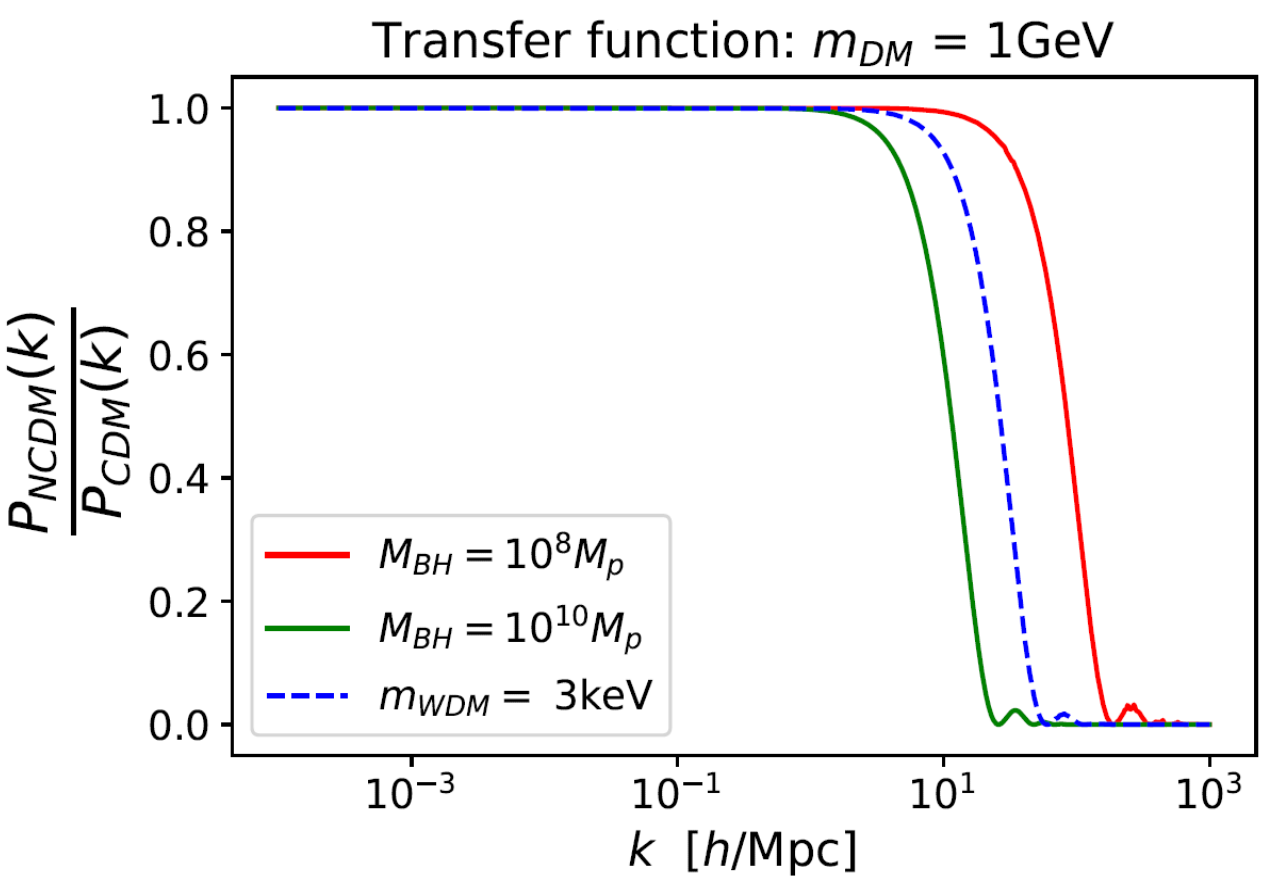


Impact on Matter Power Spectrum

NCDM from PBH evaporation:





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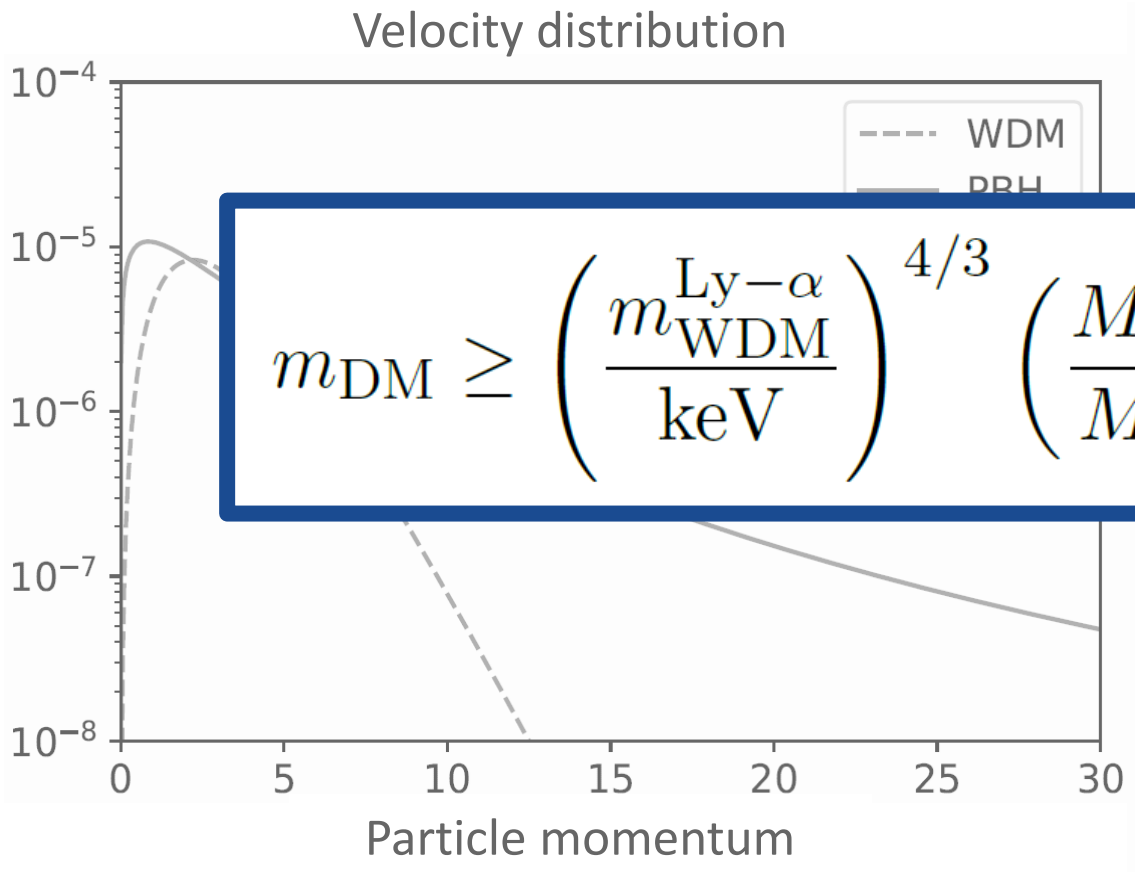
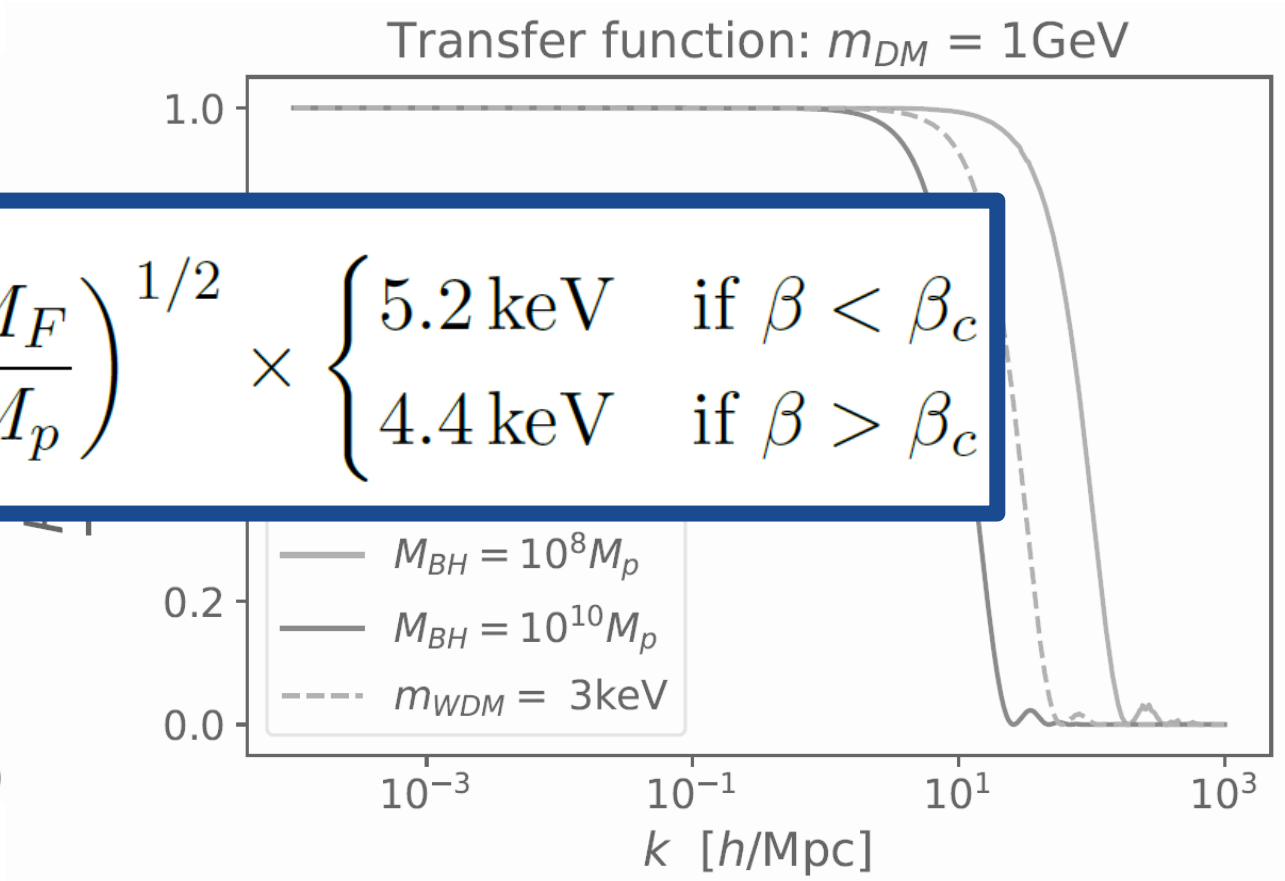
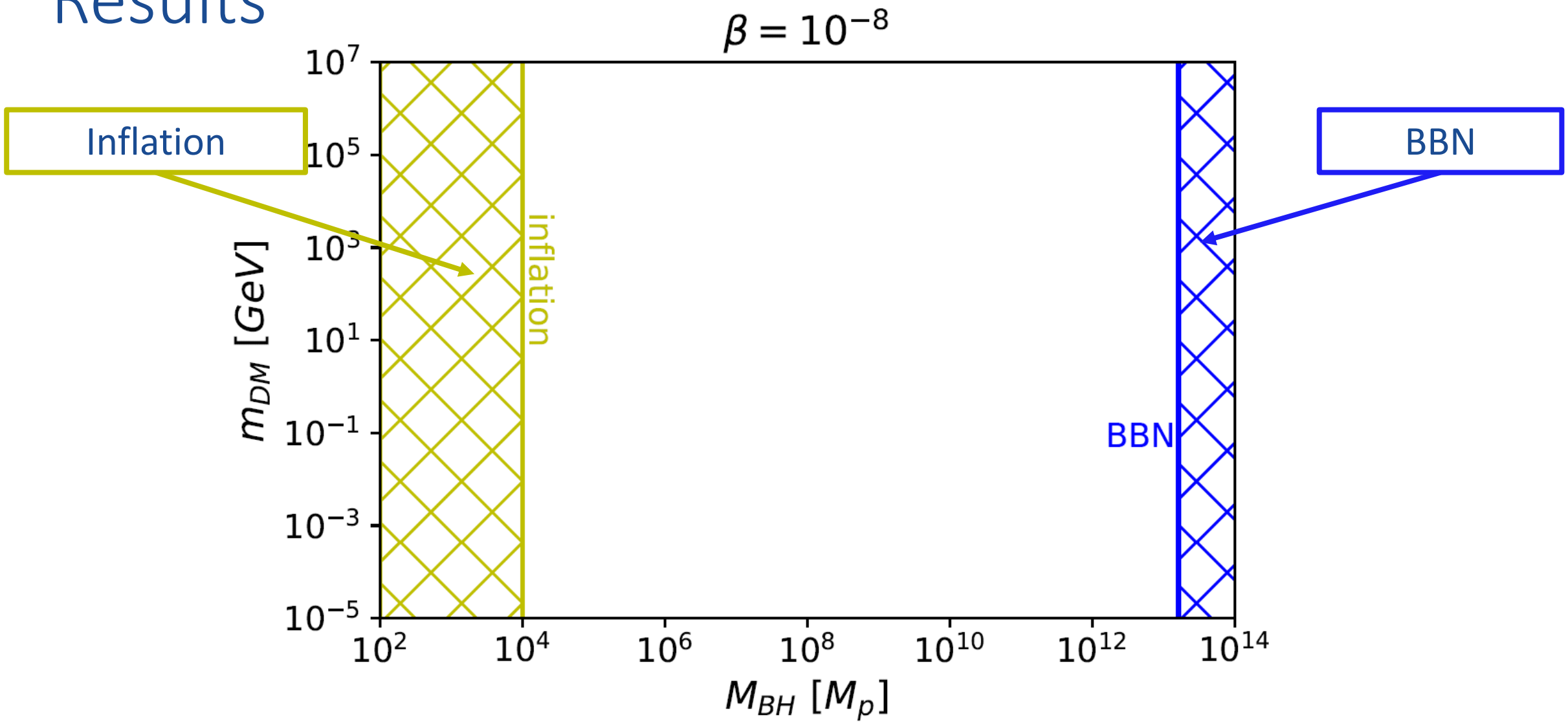


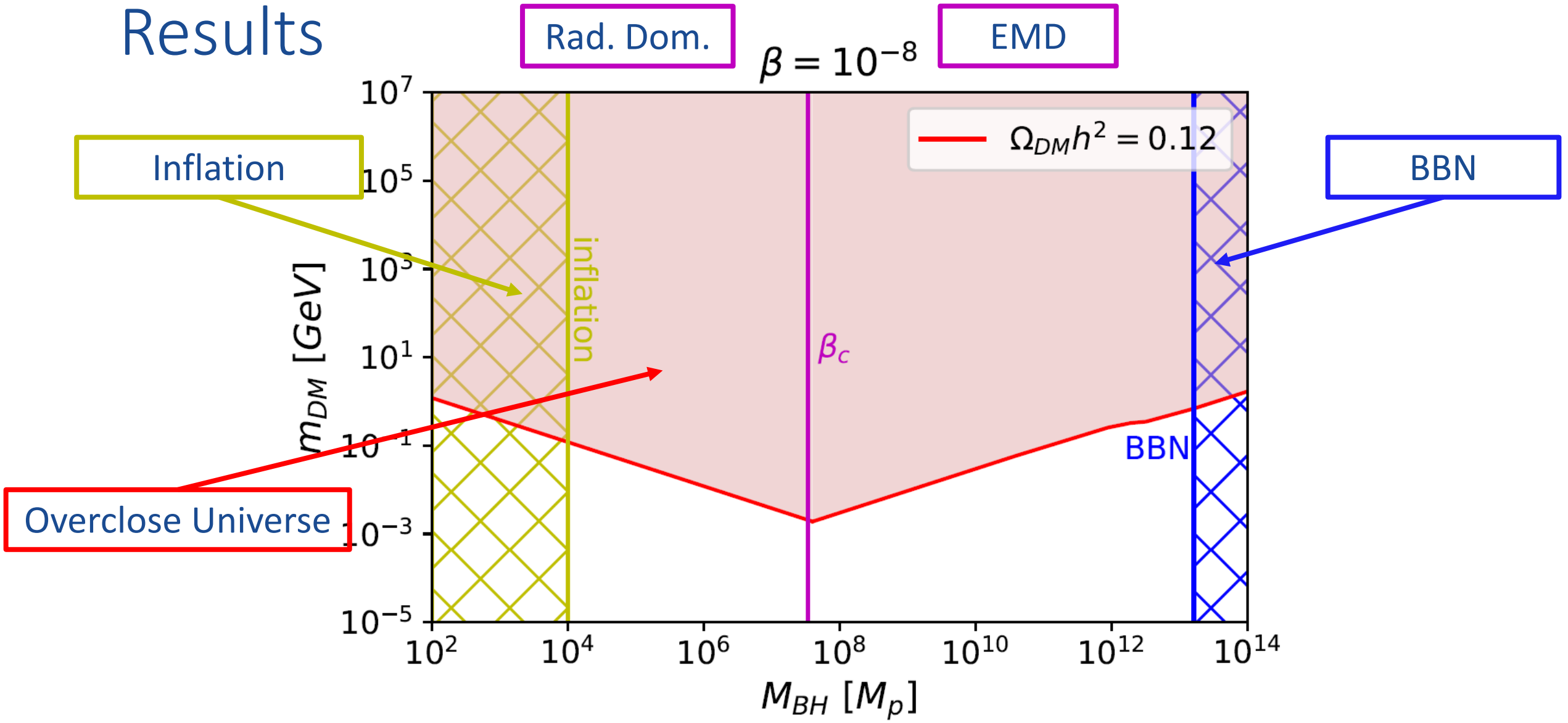
$$m_{\rm DM} \geq \left(\frac{m_{\rm WDM}^{\rm Ly-\alpha}}{\rm keV}\right)^{4/3} \left(\frac{M_F}{M_p}\right)^{1/2} \times \begin{cases} 5.2\,{\rm keV} & \text{if } \beta < \beta_c \\ 4.4\,{\rm keV} & \text{if } \beta > \beta_c \end{cases}$$



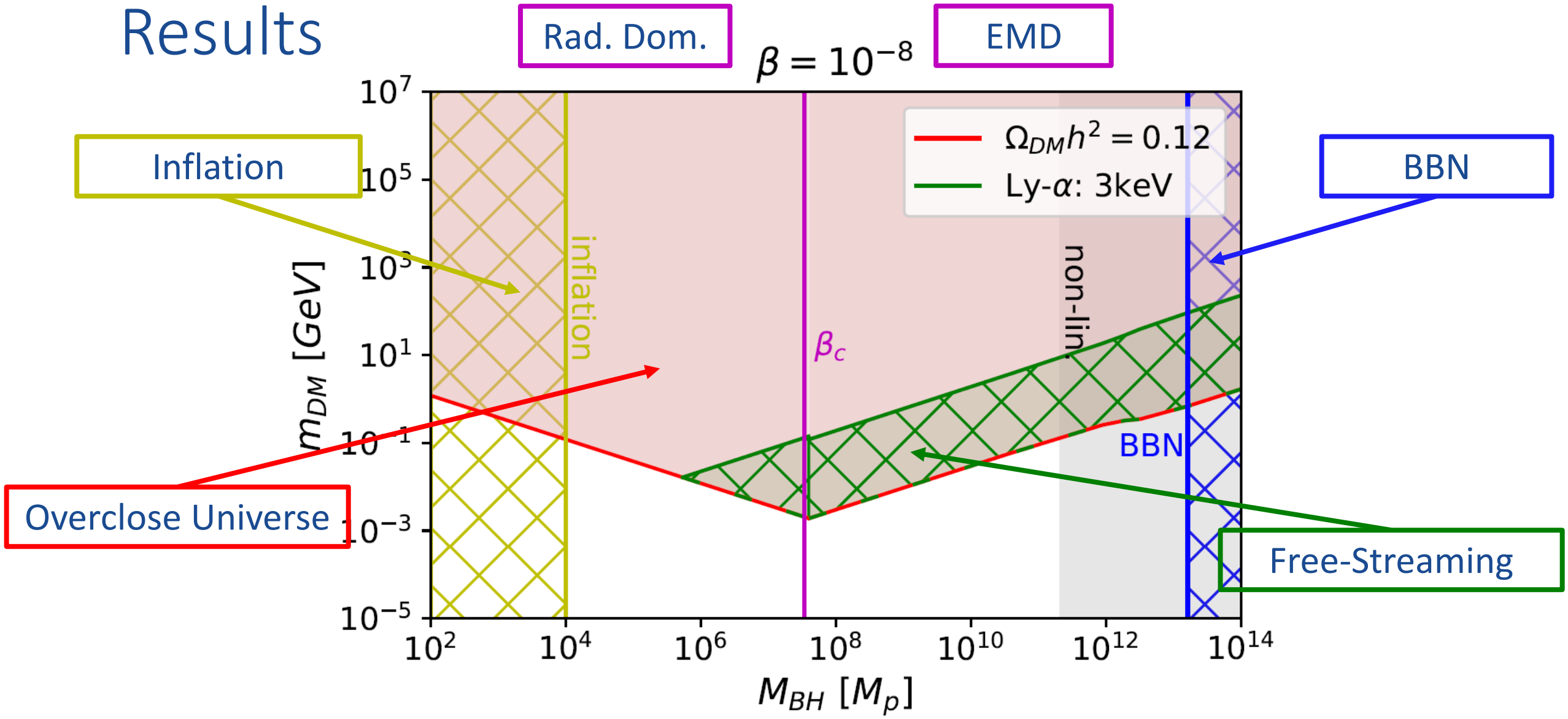
Results


$\beta = 10^{-8}$
Inflation
BBN
inflation
BBN
m_{DM} [GeV]
M_{BH} [M_p]
10^{7}
10^{5}
10^{3}
10^{1}
10^{-1}
10^{-3}
10^{-5}
10^{2}
10^{4}
10^{6}
10^{8}
10^{10}
10^{12}
10^{14}

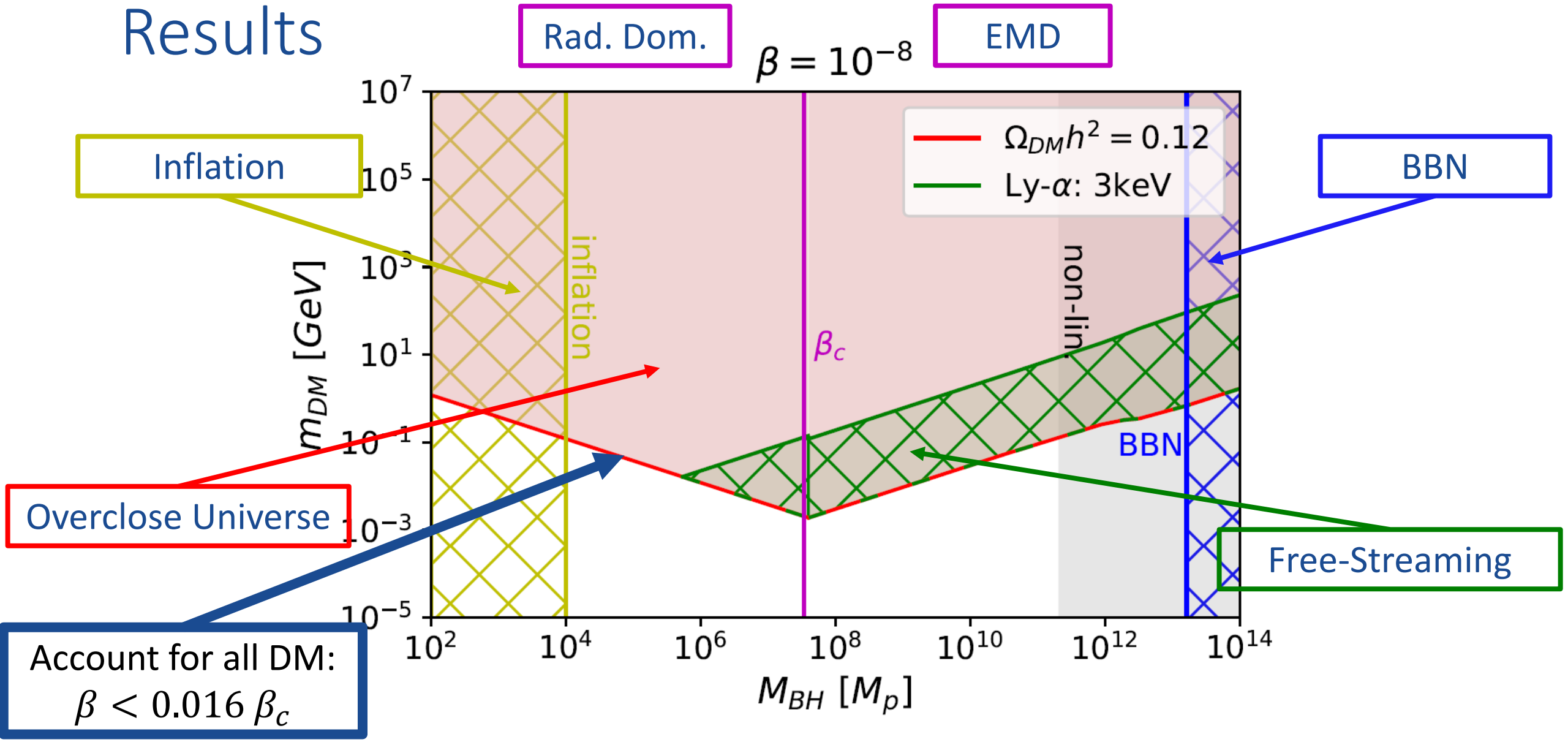
Results


Rad. Dom.
EMD
$\beta = 10^{-8}$
Inflation
BBN
Overclose Universe
$\Omega_{DM}h^2 = 0.12$
inflation
β_c
BBN
m_{DM} [GeV]
M_{BH} [M_p]
10^7
10^5
10^3
10^1
10^{-1}
10^{-3}
10^{-5}
10^2
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}

Results


Rad. Dom.
EMD
$\beta = 10^{-8}$
Inflation
BBN
Overclose Universe
Free-Streaming
$\Omega_{DM}h^2 = 0.12$
Ly-α: 3keV
inflation
β_c
non-lin.
BBN
m_{DM} [GeV]
M_{BH} [M_p]
10^7
10^5
10^3
10^1
10^{-1}
10^{-3}
10^{-5}
10^2
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}

Results


Rad. Dom.
EMD
$\beta = 10^{-8}$
Inflation
BBN
Overclose Universe
Free-Streaming
Account for all DM:
$\beta < 0.016\ \beta_c$
$\Omega_{DM}h^2 = 0.12$
Ly-α: 3keV
inflation
β_c
non-lin.
BBN
m_{DM} [GeV]
M_{BH} [M_p]
10^7
10^5
10^3
10^1
10^{-1}
10^{-3}
10^{-5}
10^2
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}

Conclusion

NCDM with only Grav. Int. from PBH evaporation can account for all DM

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Precise bound from free-streaming on NCDM mass

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Precise bound from free-streaming on NCDM mass

Lightest BH in scenario ($M_{BH} = 10^4 M_{Pl}$): $m_{NCDM} > 2$ MeV

For larger M_{BH} we can exclude m_{NCDM} up to 100 GeV