Non-Thermally Produced MeV-Scale Dark Matter

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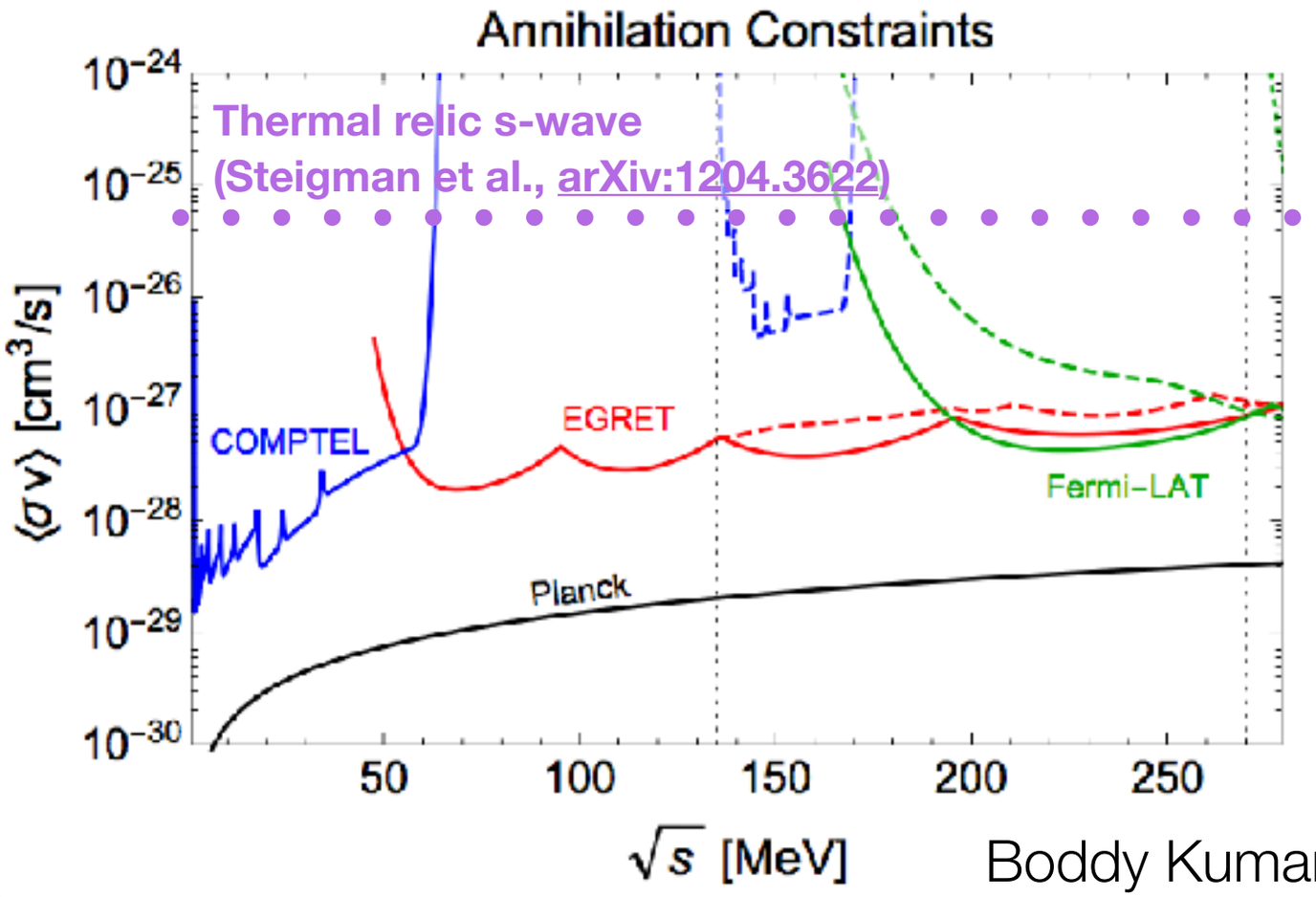
Production of MeV-Scale DM

- ☑ Thermal freeze-out: s-wave models ruled out



Boddy Kumar, arXiv:1504.04024

- ☑ Freeze-In
  - zero initial abundance
  - slow production through small couplings

Freeze-In Examples

- ☑ Renormalizable interactions
  - Example: Higgs Portal $\mathcal{L} \supset \lambda(\phi^\dagger\phi)(H^\dagger H)$
  - $T_{fi} \sim m_H$
- ☑ Non-Renormalizable interactions (“UV Freeze-In”)
  - Example: $\mathcal{L} \supset \frac{1}{\Lambda}\phi F_{\mu\nu}F^{\mu\nu}$
  - $T_{fi} \sim T_{RH}$

Elahi Kolda Unwin arXiv:1410.6157

Detecting DM @ MeV

- ☑ Direct detection
  - challenging because of low recoil energies
- ☑ Production in the lab
  - challenging due to tiny couplings to the SM
- ☑ Indirect detection
  - very promising
  - only few decay/annihilation channels

Indirect Detection Signals

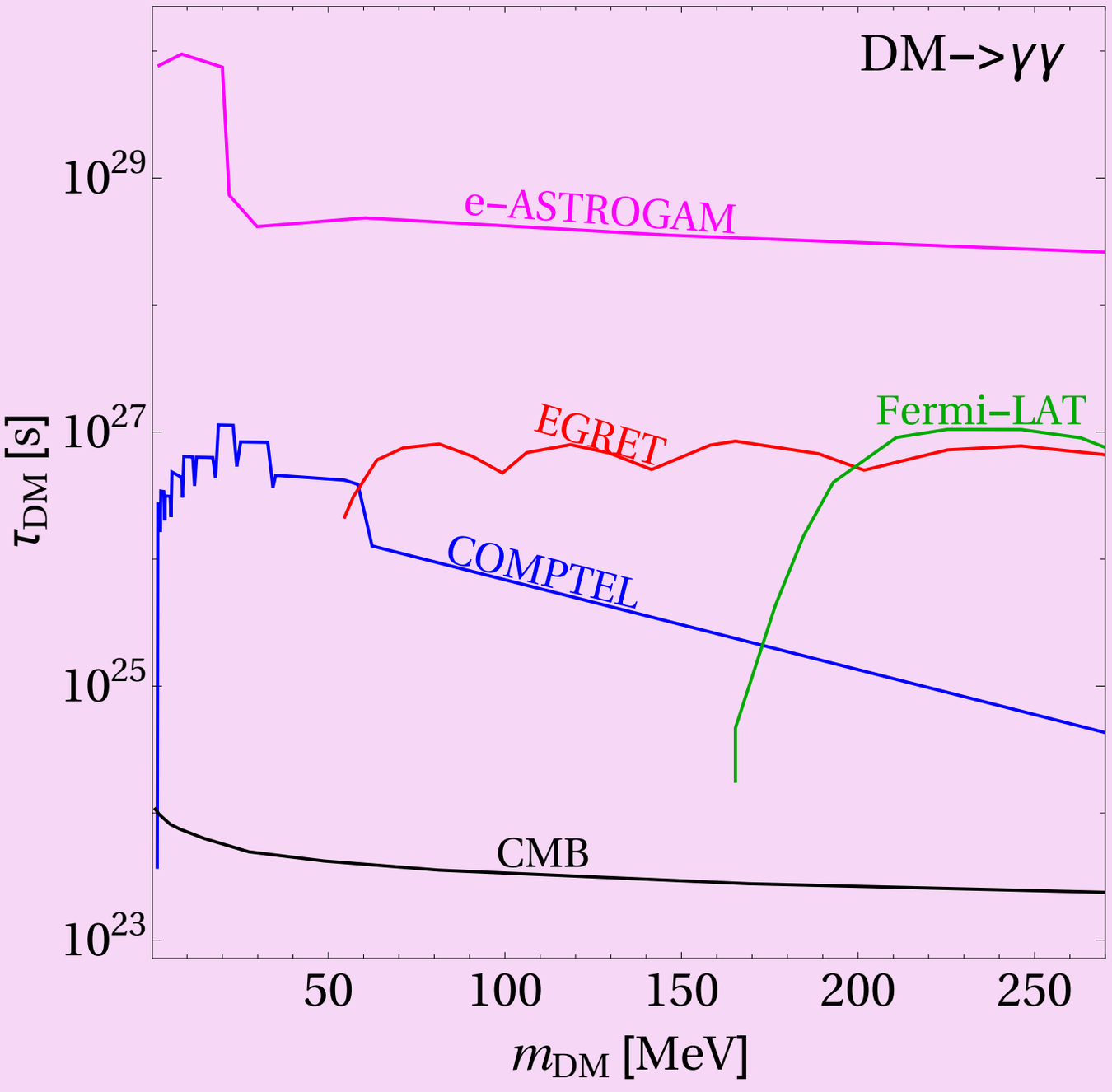
- DM decay
  - Example: $\phi \to \gamma\gamma$ via $\mathcal{L} \supset \frac{1}{\Lambda}\phi F_{\mu\nu}F^{\mu\nu}$
  - Decay Rate:

$$\Gamma \simeq 2.4 \times 10^{24}\,\mathrm{sec} \times \left(\frac{\mathrm{MeV}}{m_\phi}\right)^3 \left(\frac{\Lambda}{10^{16}\,\mathrm{GeV}}\right)^2$$

  - Other channels: $\phi \to \nu\nu$, $\phi \to \pi^0\gamma$, $\phi \to \pi^0\,\pi^0$, $\phi \to e^+e^-$

Indirect Detection Signals

- ☑ DM d
  - Ex
  - De
  - Of



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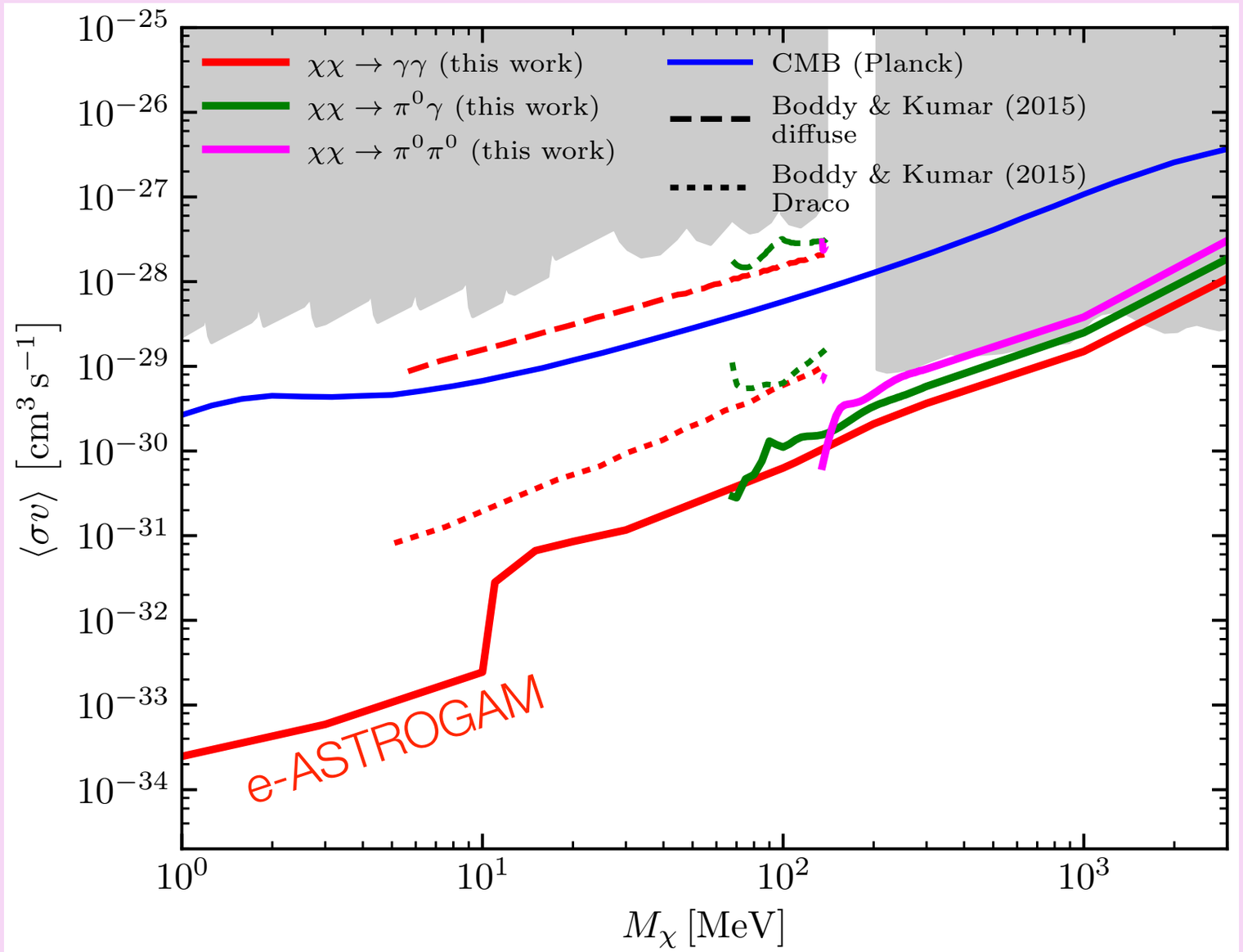
  - Other channels: $\phi \to \nu\nu$, $\phi \to \pi^0\gamma$, $\phi \to \pi^0\,\pi^0$, $\phi \to e^+e^-$
- DM annihilation
  - $\chi\chi \to \gamma\gamma$
  - $\chi\chi \to \pi^0\gamma$, $\pi^0\,\pi^0$
  - $\chi\chi \to e^+e^-$, $\nu\nu$
  - $\chi\chi \to \phi\phi \to 4\gamma$

Indirect Detection Signals

- DM d
  - Ex
  - De
  - Of
- DM a
  - XX
  - XX
  - XX
  - XX



Bartels Gaggero Weniger arXiv:1703.02546

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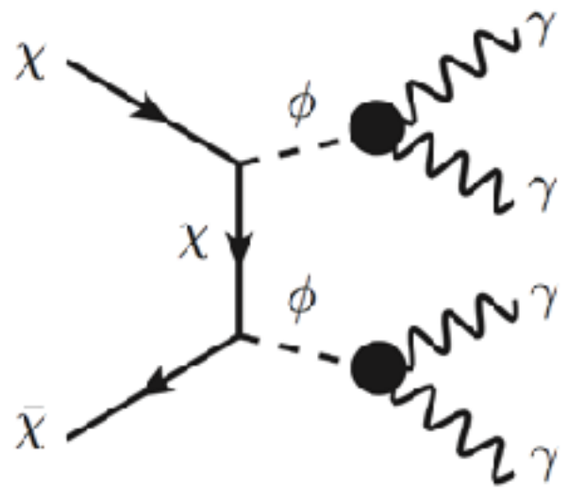
Example for χχ → ϕϕ → 4γ

☑ Fermionic DM χ, dark sector scalar ϕ

$$\mathcal{L} \supset \frac{\alpha}{4\pi\Lambda} F_{\mu\nu}F^{\mu\nu}\phi + y\,\phi\bar{\chi}\chi\,,$$



☑ DM production via

$$m_\phi \simeq m_\chi$$

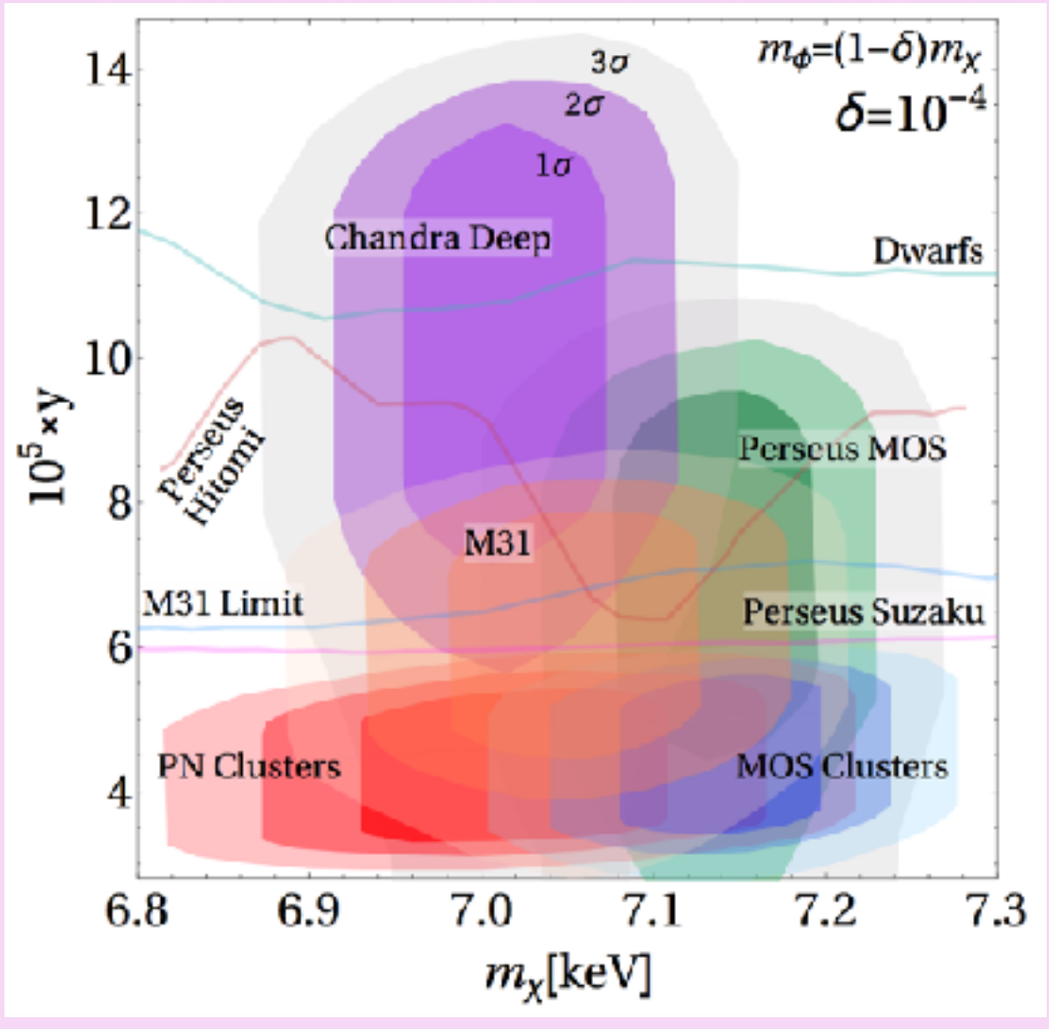
- Freeze-In of ϕ, decay to χ
- Production of ϕ via misalignment, decay to χ
- Thermalization of ϕ, freeze-in of χ via ϕϕ → χχ

Brdar JK Liu Wang arXiv:1710.02146

Example for χχ → ϕϕ → 4γ

- ☑
- ☑

Originally developed for keV-scale DM



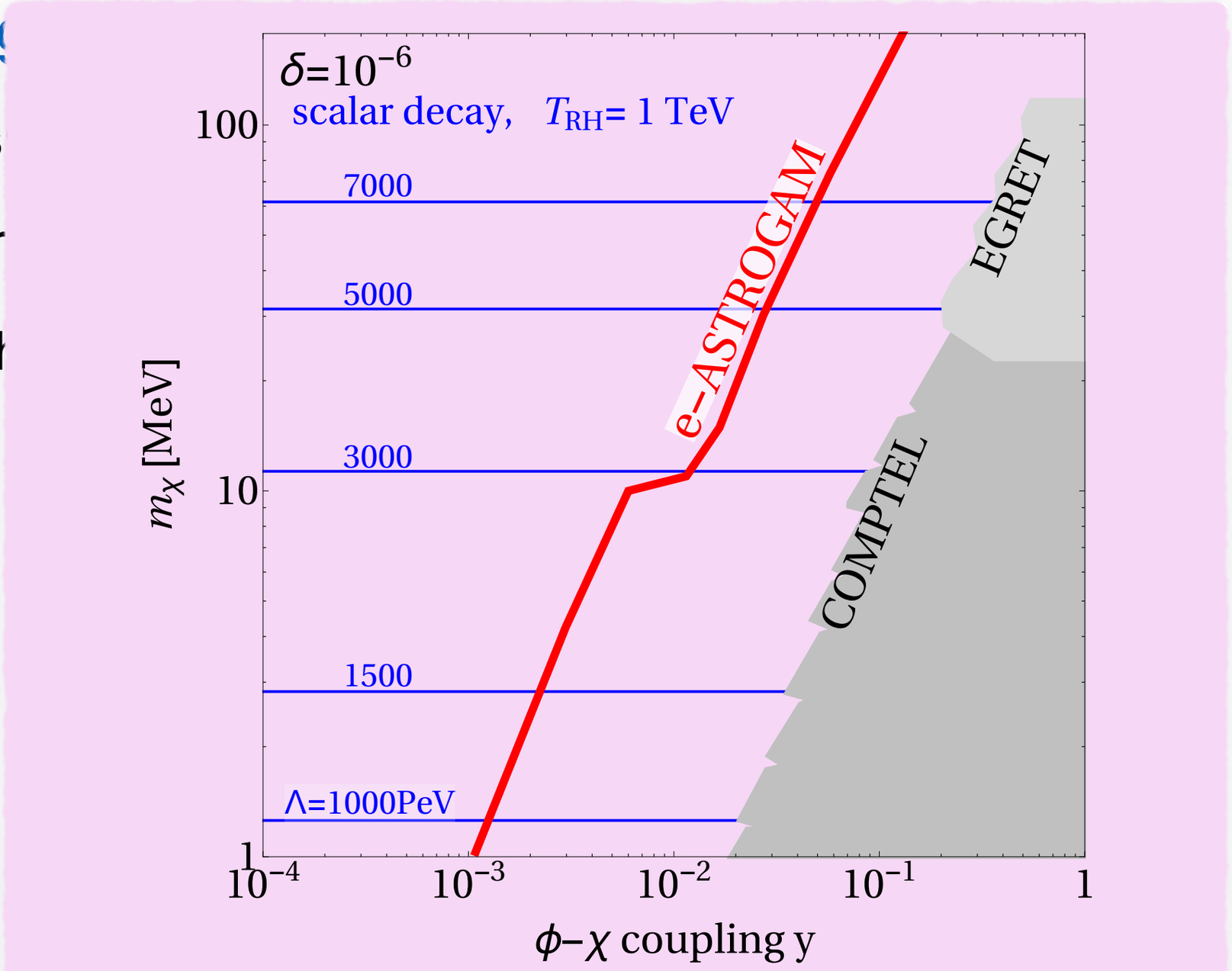
Brdar JK Liu Wang arXiv:1710.02146

MeV Gamma Rays from $\chi\chi \to \phi\phi \to 4\gamma$

- ☑ γ-ray signature:
  - box-shaped spectrum
  - may resemble line if $m_\phi \simeq m_\chi$ (e.g. in SUSY?)
  - morphology may not trace DM density if $v / \tau_\phi \gtrsim 0.1$ kpc

MeV Gamma Rays from χχ → ϕϕ → 4γ

- ☑ γ-ray sig
  - box-s
  - may r
  - morph



based on Brdar JK Liu Wang arXiv:1710.02146

Summary

- ☑ Production of MeV-scale DM likely via Freeze-In
- ☑ Possible signatures
  - γ lines
  - Peaked spectrum from final state radiation
  - box-shaped spectrum from 2-step annihilation/decay
  - morphology may not trace DM density

Thank you!

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