Asymmetric Atomic Dark Matter

w/ D.E. Kaplan, G. Krnjaic and K. Rehermann

JCAP 1005:021/arXiv:0909.0753 + arXiv:1105.tonight?

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PHENO ’11

Plan

- Motivation
- Field Content
  - Cosmology
  - Direct Detection
- Summary

MOTIVATION

Why Atoms?

- Nature likes bound states.
- DD:
  - ➡Structure
  - ➡Lite
- Why not?

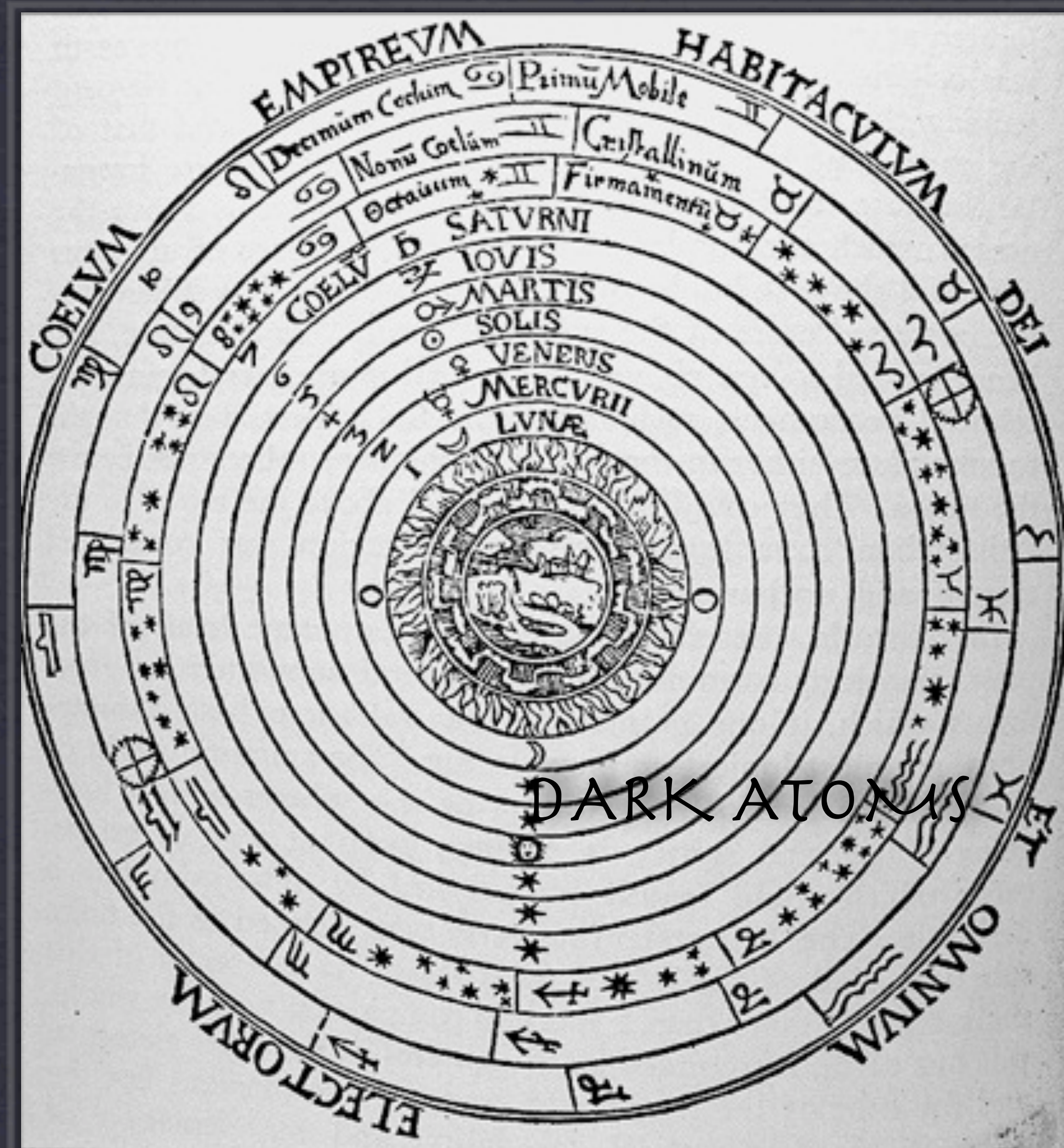
FIELD CONTENT

- Atomic Constituents
- Asymmetry
- Symmetry breaking

	$SU(2)_D$	$U(1)_X$	$\mathcal{Z}_2$
$\mathbf{E}$	$\overline{\square}$	-1	-1
$\mathbf{E}^c$	$\square$	-2	-1
$\varphi_{\mathbf{e}}$	$\square$	1	-1
$\mathbf{P}$	$\square$	1	1
$\mathbf{P}^c$	$\overline{\square}$	2	1
$\varphi_{\mathbf{p}}$	$\overline{\square}$	-1	1
$\mathcal{X}$	$\begin{smallmatrix}\square & \square \\ \square & \end{smallmatrix}$	3	1
N_{Heavy}	0	0	1
N_{Light}	0	0	1

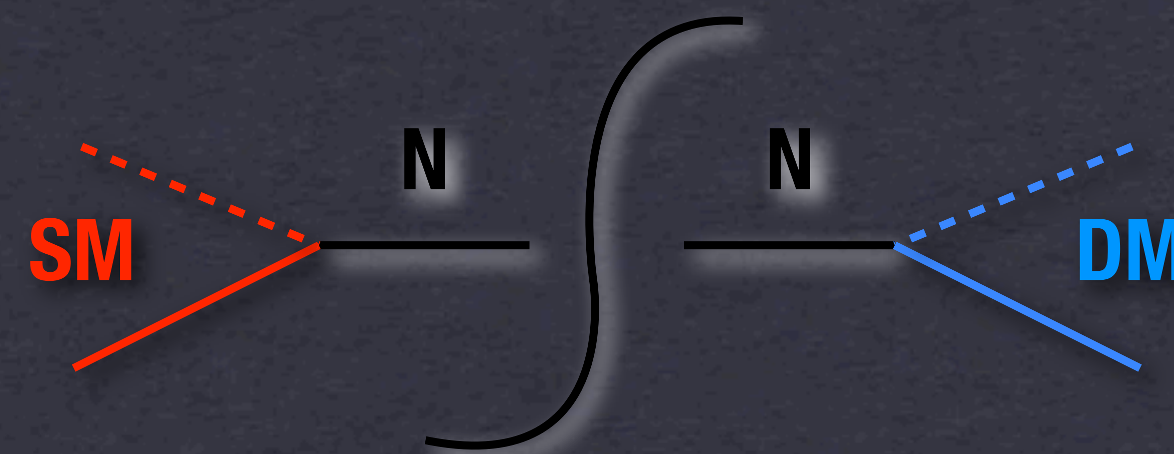
Overview

- Asymmetry
- Recombination
- Halo



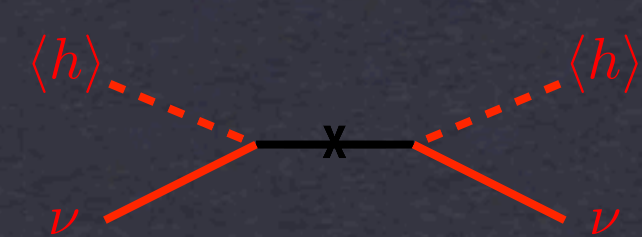
$$\mathcal{L} \supset -\frac{M_{N_i}}{2} N_i^2 + y^{ij} N_i l_j h + \lambda_E^i N_i E \varphi_e + \lambda_P^i N_i P \varphi_p$$

Asymmetry



- Asymmetric DM has long history:
  - S. Nussinov, Phys. Lett. B 165, 55 (1985)
  - M. A. Luty Phys. Rev. D45, 455-465 (1992)
  - D. B. Kaplan, Phys. Rev. Lett. 68, 741 (1992)
  - R. Kitano and I. Low, Phys. Rev. D 71, 023510
  - D. E. Kaplan, M. Luty and K. Zurek 2009
  - Falkowski et al 1101.4936

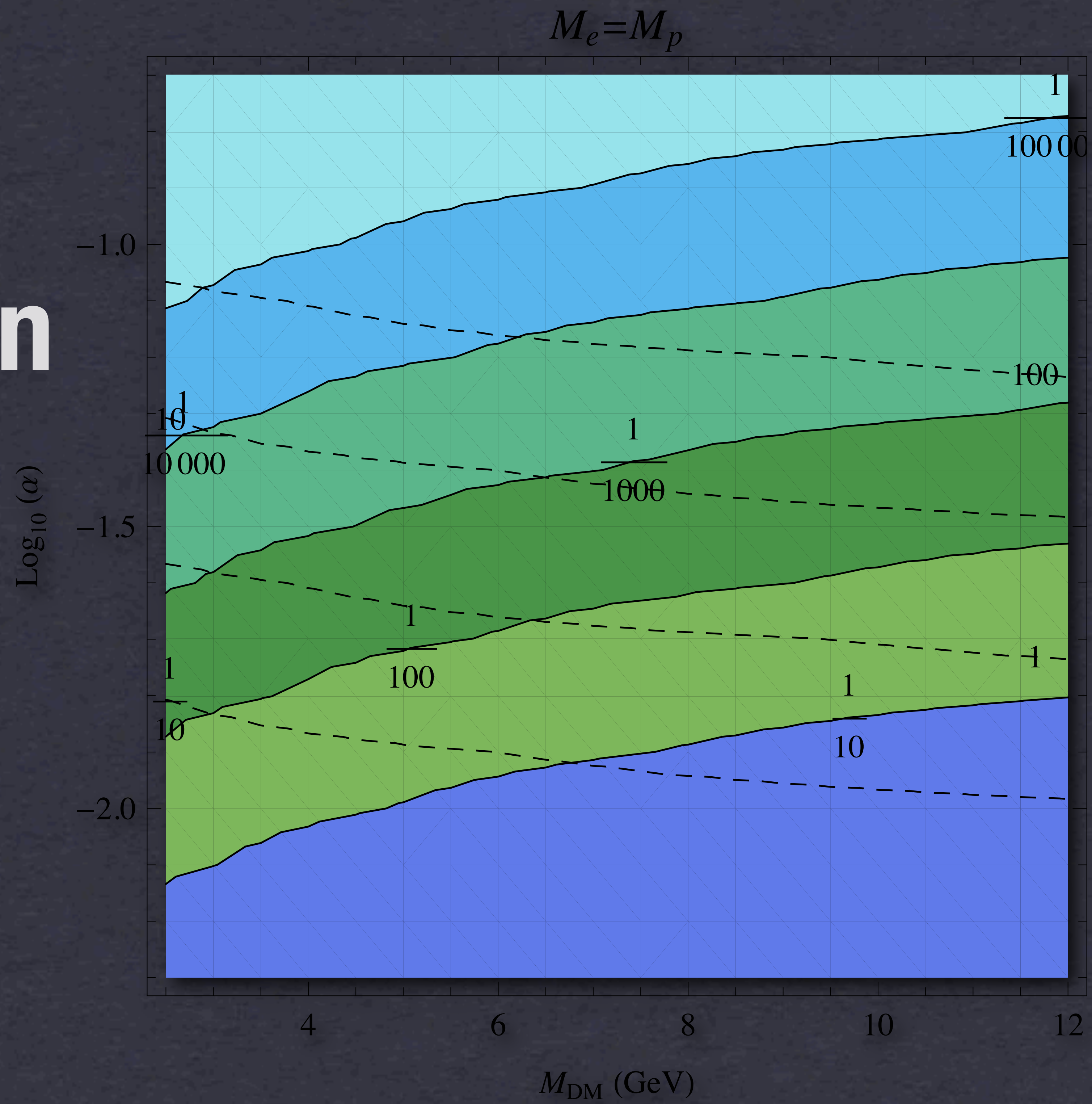
- Important:
  - Annihilate symmetric piece --> $U(1)_D$!!
  - Get rid of the scalars! --> $\mathcal{L} \supset \kappa(\varphi_e \varphi_p)^2$
  - Washout <-> “Strong-Strong” <-> See-saw



$$\mathcal{L} \supset -\frac{M_{N_i}}{2} N_i^2 + y^{ij} N_i l_j h + \lambda^i N_i \Psi \Phi$$

Recombination

- $SU(2)_D$ breaks to $U(1)_D$.
- 4 distinct species.
- `Positronium' simplest.



Halo: Structure

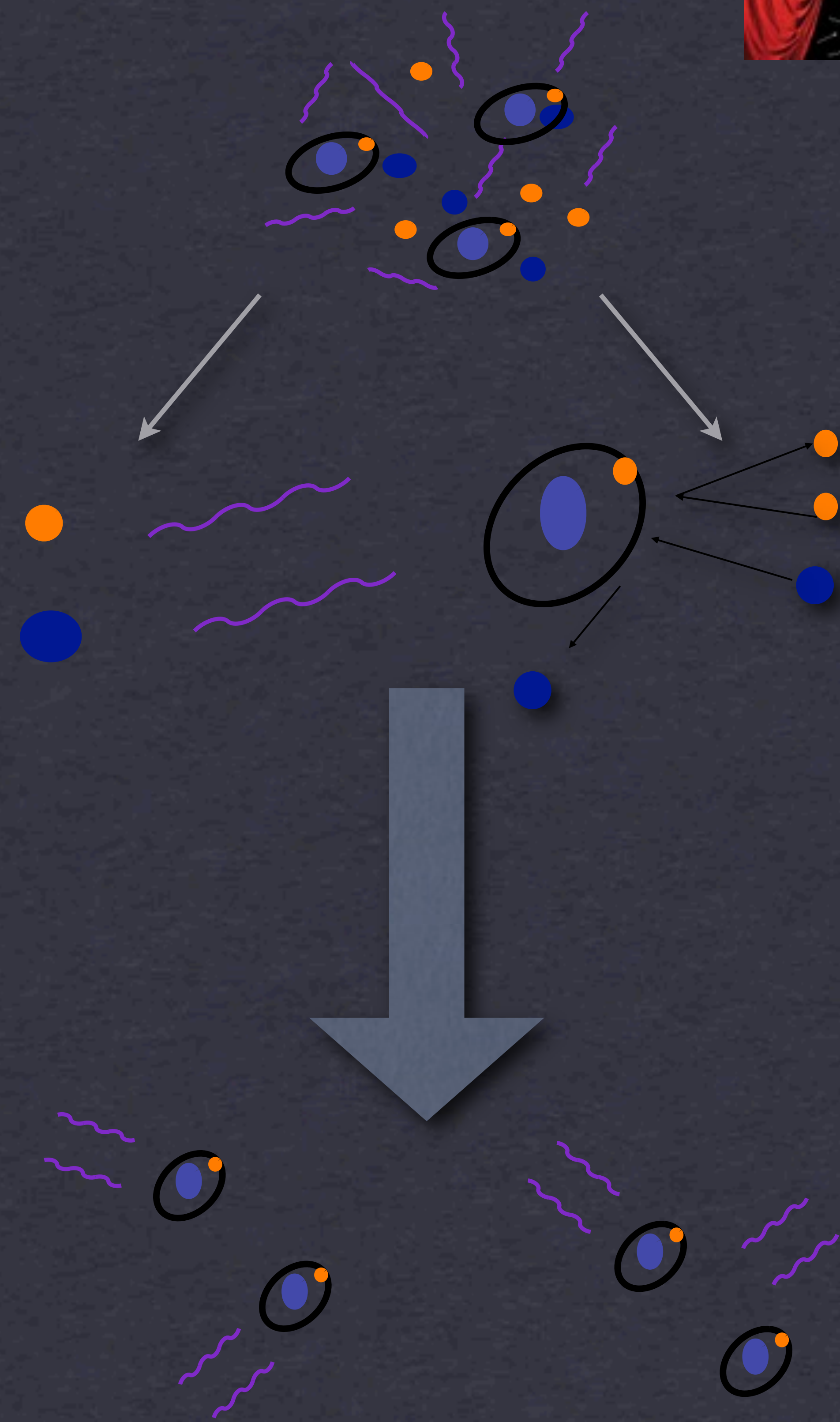
- Late decoupling.

$$T_{\rm Dec} \simeq 0.1\, \alpha_{\rm D}^{4/3} \left(\frac{1}{X_e}\right)^{2/3} \left(\frac{m_{\rm Ion}}{\rm GeV}\right)^{7/3} {\rm keV}$$

- Smoothing on interesting scales. (Missing satellites.)

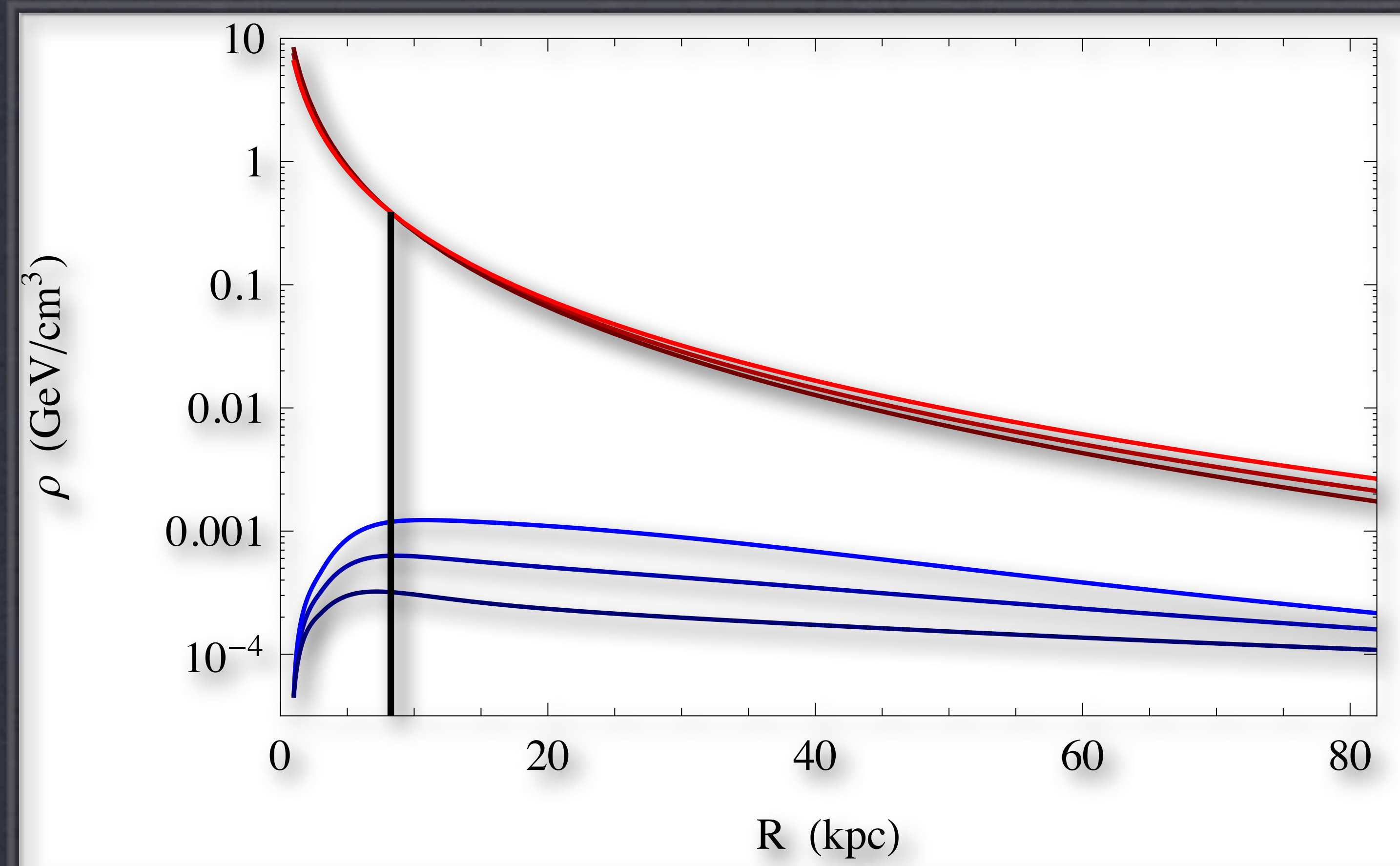
$$M_{\rm CDM}^{\rm Grow} > 10^{-4} \left(\frac{T_{\rm Dec}}{10\,{\rm MeV}}\right)^{-3} M_\odot$$

$$M_{\rm ADM}^{\rm Grow} > 10^{5} \left(\frac{T_{\rm Dec}}{10\,{\rm keV}}\right)^{-3} M_\odot$$



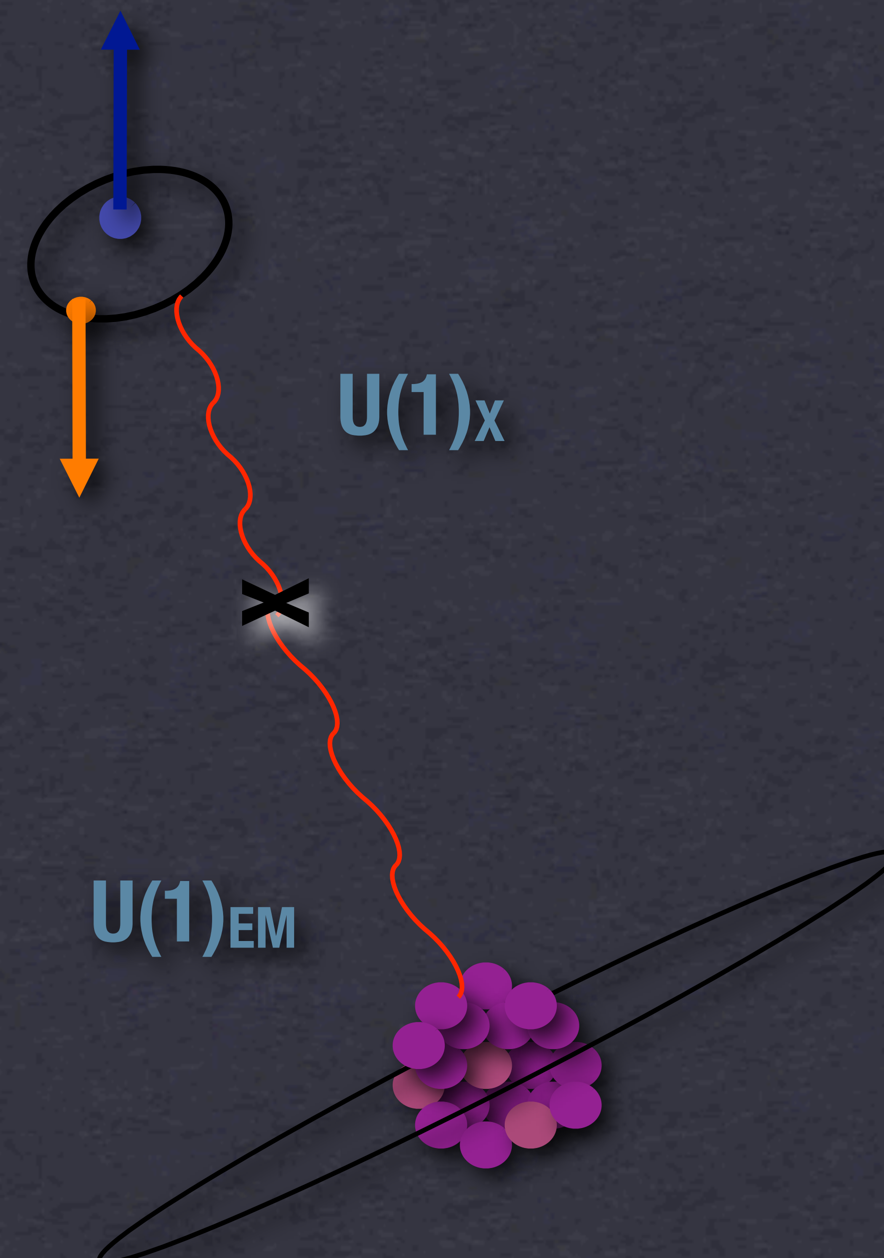
Halo: Ions

- Ions scatter rapidly.
- Thermal equilibrium!
- $n_{\mathrm{Ion}}(r) \propto e^{-U(r)/\langle T \rangle}$



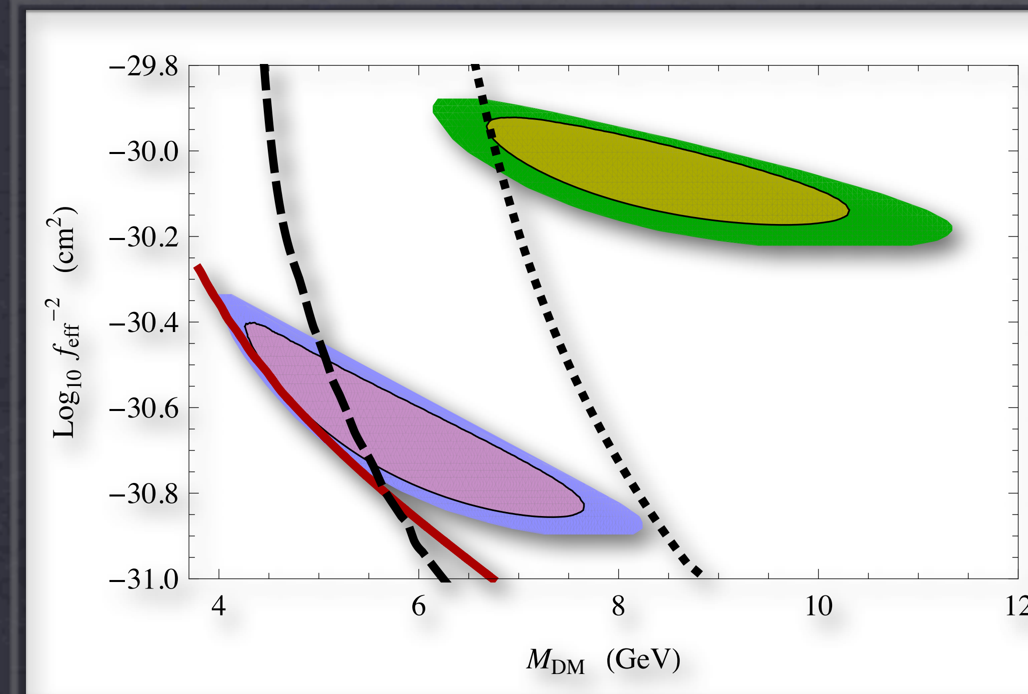
Kinetic Mixing

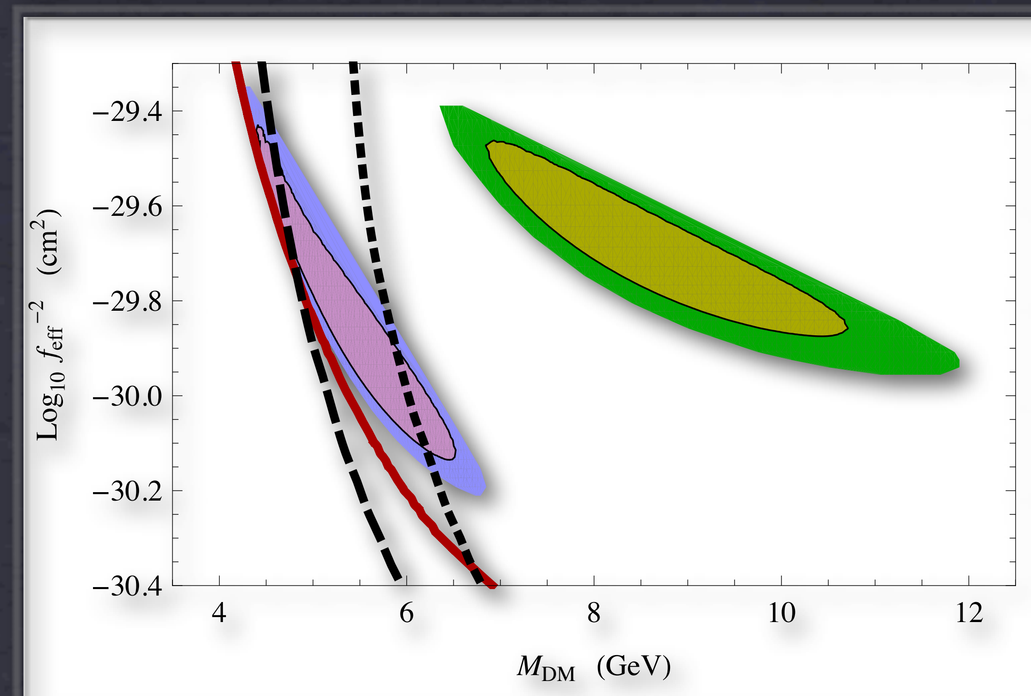
- $U(1)_X$ <--> $U(1)_Y$
- Spin-dependent Yukawa interaction.
- Hyperfine transition.



Parameter Space

- DAMA is hard.
- CoGeNT and CDMS at 95%.
- CoGeNT is consistent with CRESST.





Conclusion

- Dark Atoms can be CDM.
- Interesting Cosmology.
- Distinct direct detection.
- More to come...