Dark Matter Out of Seclusion *

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- arXiv:0903.0363
- arXiv:0903.3396

Overview

- Secluded WIMPs
- Out of seclusion via
  - Colliders
    - Higgs-strahlung at B-factories
  - Direct detection experiments
    - Endothermic and exothermic inelastic scattering
    - Higher order elastic scattering

Secluded Dark Matter

Pospelov, Ritz, Voloshin '07

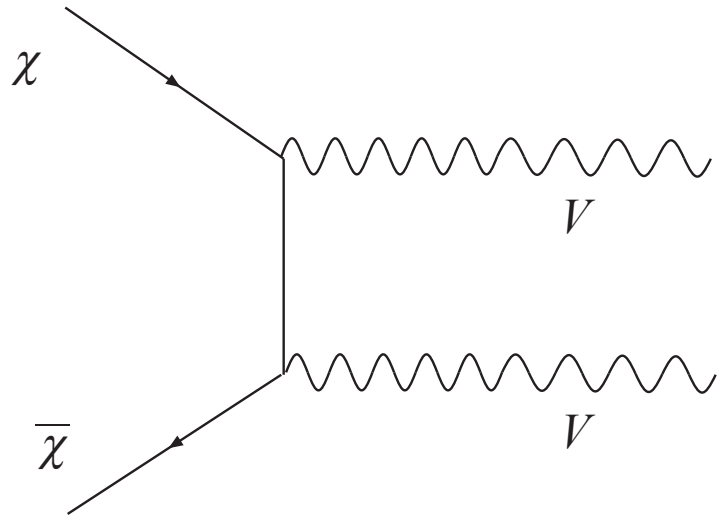
$$\chi \text{ ----- } V_{\mu\nu} B^{\mu\nu} \text{ ----- SM}$$

Holdom '86

"Secluded" regime

- $m_\chi > m_V$
  - Annihilation via $\overline{\chi}\chi \to VV$
  - Relic abundance independent of kinetic mixing
  - Makes direct detection, collider signatures tricky if mixing small.

  Can't rule out WIMP hypotheses in principle if secluded



Astrophysical signatures

1) Light mediator $\longrightarrow$ enhanced galactic annihilation cross section

- e.g. Sommerfeld enhancement: long range force distort wavefunctions near the origin from the plane wave to the Coulomb-type.

Arkani-Hamed, Finkbeiner, Slatyer, Weiner '08

Pospelov, Ritz '08

$$\mathcal{N} \sim \frac{\pi\alpha'}{v}$$

2) $m_V \leq$ GeV $\Longrightarrow$ vector won't decay to (anti-)protons by kinematics

Connection with PAMELA, ATIC, FERMI, HESS, ...?

B-factory Signatures

BB, Pospelov, Ritz '09;
Essig, Schuster, Toro '09;
Reece, Wang '09;

B-factories

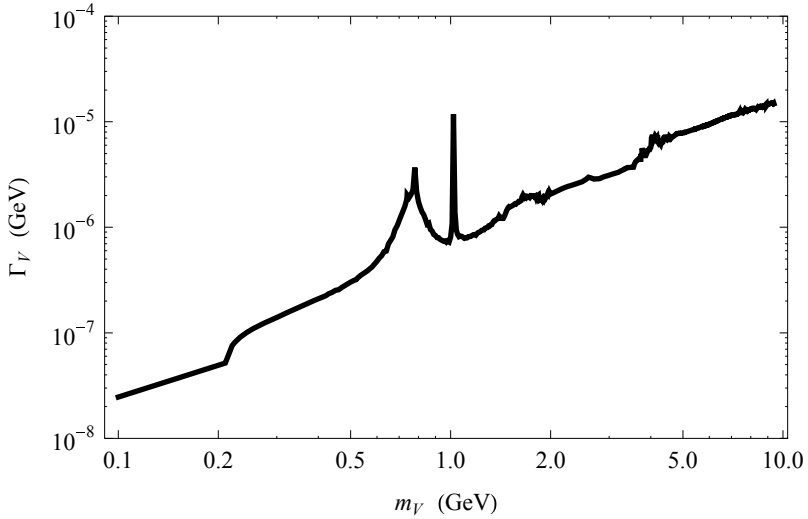
B-factory (BaBar and Belle) advantages:

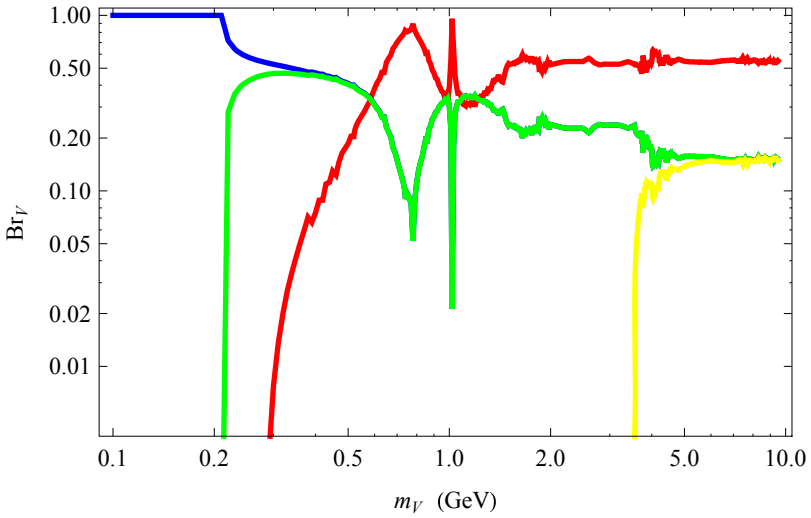
- Large data sets ~ 500 fb^{-1}
- COM energy $\sqrt{s} \simeq 10$ GeV, close to masses of new particle

$$\mathcal{L}_{int} = -\frac{\kappa}{2} V_{\mu\nu} F^{\mu\nu} + \frac{m_V^2}{v'} h' V_\mu^2$$

- Higgs′-strahlung: $e^+e^- \to \gamma^*, V^* \to h'V$
- Cross section $\sigma \sim 20$ fb
- Leads to 6 lepton final state

V_μ decays

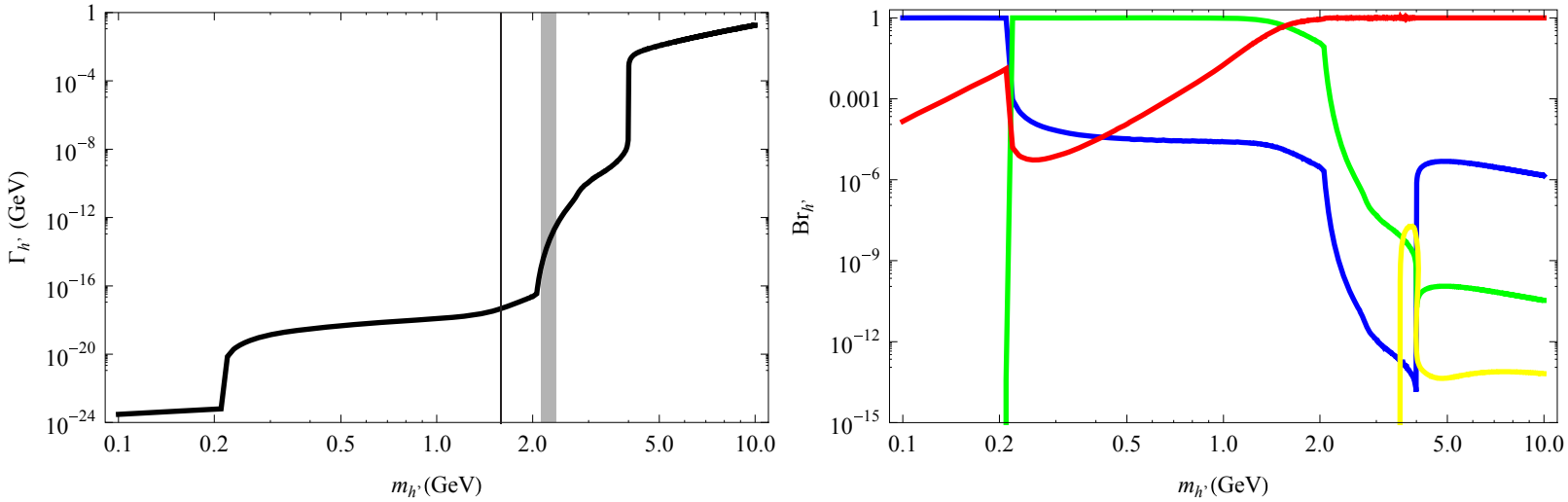




- $V \rightarrow$hadrons (Red)
- $V \rightarrow e^+e^-$ (Blue)
- $V \rightarrow \mu^+\mu^-$ (Green)

V_μ always has a significant branching to leptons

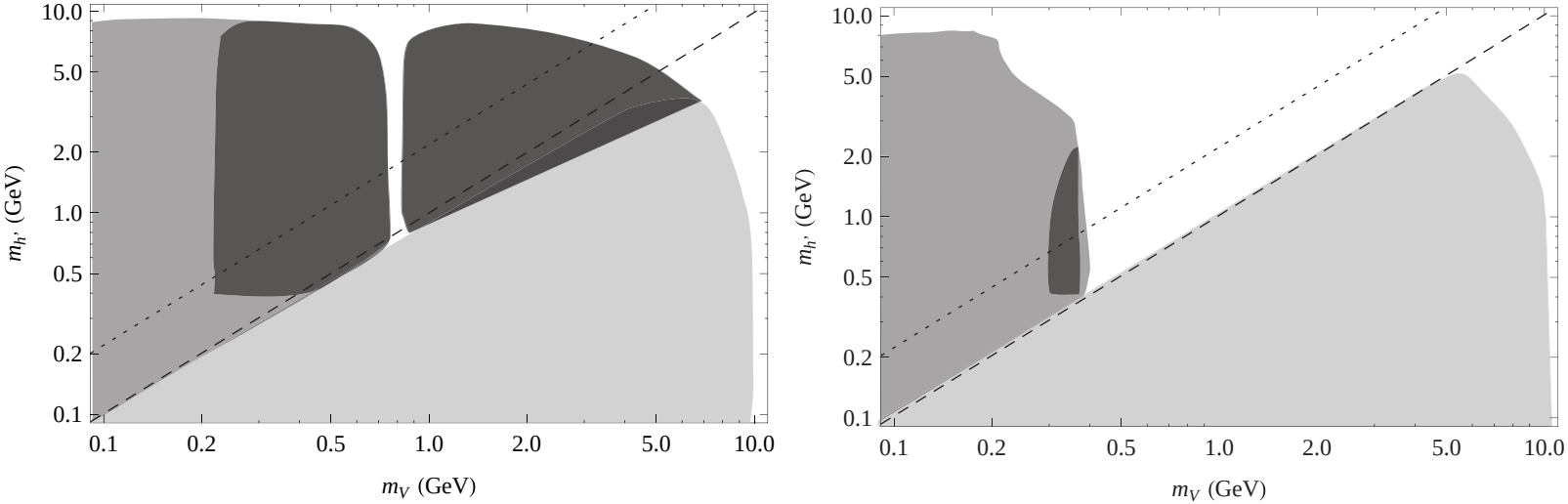
h' decays



- $h' \to VV$ (Red)
- $h' \to e^+e^-$ (Blue)
- $h' \to \mu^+\mu^-$ (Green)

-Decays of h' depend on whether $m_{h'} > m_V$ or $m_{h'} < m_V$

Sensitivity



- $2l+$ missing energy (light)
- $6e$ (medium)
- 6μ (dark)

Direct Detection

Finkbeiner, Slatyer, Weiner, Yavin '09;
BB, Pospelov, Ritz '09;

Multi-component WIMPs

- If WIMP is a complex scalar or Dirac fermion, the real components χ, χ' can be split after U(1)$_S$ is broken so that $\Delta m = m_{\chi 2} - m_{\chi 1}$

$$\mathcal{L} = \sum_{i=1,2} \left(i\overline{\chi}_i \overline{\sigma}_\mu \partial_\mu \chi_i - \frac{1}{2}(m\chi_i \chi_i + \text{h.c.}) \right) - ie' V_\mu (\bar{\chi}_1 \overline{\sigma}_\mu \chi_2 - \bar{\chi}_2 \overline{\sigma}_\mu \chi_1)$$

- No tree level elastic scattering process $\chi_1 N \to \chi_1 N$

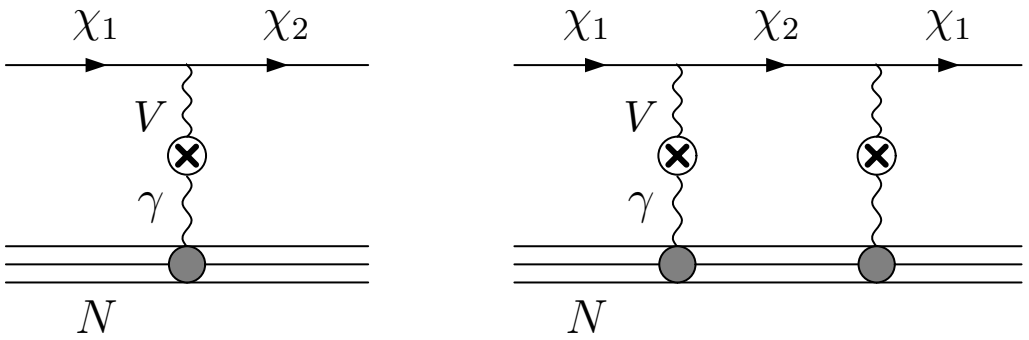
- Example of *inelastic dark matter*

Smith, Weiner '01

- Direct detection depends sensitively on Δm

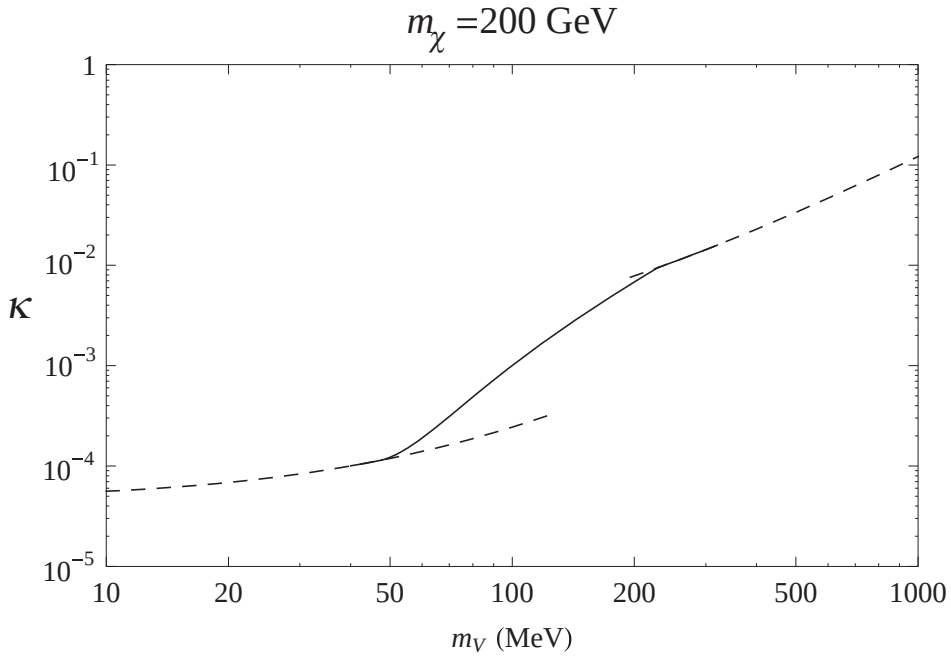
Rich scattering structure

- *Endothermic inelastic*: $\chi_1 N \to \chi_2 N$
- *Exothermic inelastic*: $\chi_2 N \to \chi_1 N$ (depends on χ_2 population)
- *Second-order elastic*: $\chi_1 N \to$ virtual states $\to \chi_1 N$



Elastic: $\chi_1 N \to \chi_1 N$

- CDMS constraints ($\Delta m = 10$ MeV)



Sensitivity diminishes as WIMP probes nucleus

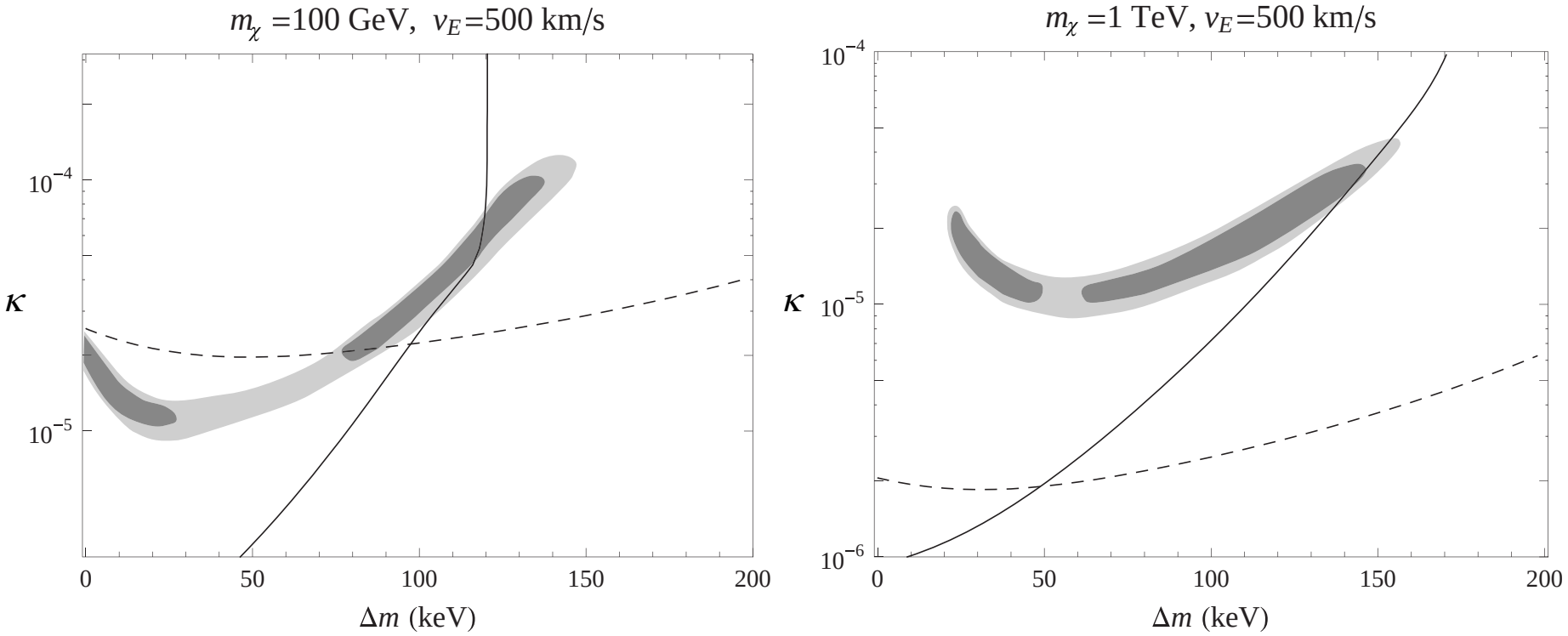
Exothermic: $\chi_2 N \to \chi_1 N$

- Requires substantial population of excited WIMPs χ_2
- Decay of χ_2 in 'minimal' U(1)$_S$ model:
  - $\Delta m > 2m_e \Longrightarrow$ rapid decay $\chi_2 \to \chi_1 + e^+ e^-$
  - $\Delta m < 2m_e \Longrightarrow$ Loop induced $\chi_2 \to \chi_1 + 3\gamma$

$$\tau > 4 \times 10^{-47}\,\mathrm{GeV} \times \left(\frac{\kappa}{10^{-3}}\right)^2 \left(\frac{\Delta m}{100\,\mathrm{keV}}\right)^{13} \left(\frac{100\,\mathrm{MeV}}{m_V}\right)^4$$

- χ_2 lifetime longer than the age of the universe for small Δm.

Exothermic: $\chi_2 N \rightarrow \chi_1 N$



- DAMA preferred region 90(99)% CL - dark(light)
  - endothermic (solid)
  - exothermic (dashed)

Conclusions

- Secluded WIMPS
- B-factory signals:
  - Higgs′-strahlung $\rightarrow$ multi-lepton final state
  - Probe $U(1)_S$ couplings $\kappa \sim O(10^{-2} - 10^{-3})$
- Rich direct detection phenomenology
  - Endothermic, exothermic, and (2nd order) elastic scattering provide sensitivity for different ranges of parameter space