Dark Matter Accretion in Neutron Stars

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Based on
Work in Preperation (arXiv: hep-ph/1808.vwxyz)
in collaboration with Y. Genolini and T. Hambye

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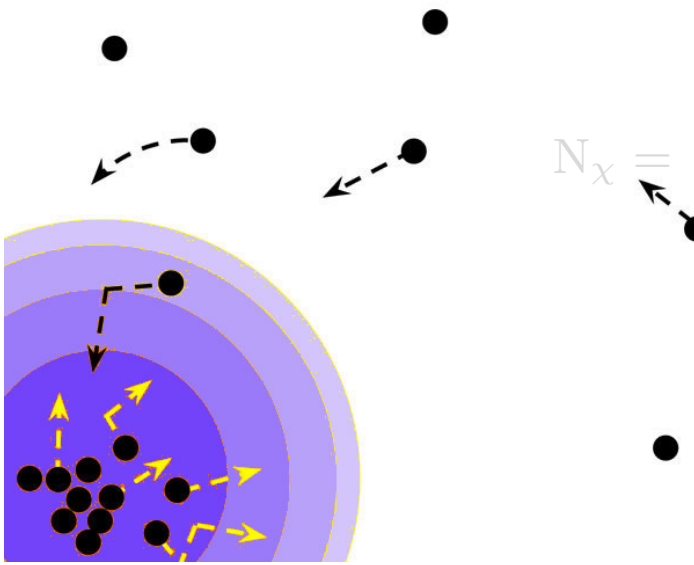
  - Dark Matter Elastic Scattering off Fermi-Degenerate Neutrons
- Consequences: New Constraints on Asymmetric Bosonic Dark Matter
  - Black Hole Formation without Bose-Einstein condensate
  - Black Hole Formation with Bose-Einstein condensate
- Conclusions

Introduction

- If DM (χ) has a non vanishing $\sigma_\chi \tau$, it can be captured in celestial objects. Press and Spergel '85, Griest and Seckel '86, Gould '87, Goldman '89
- Dynamics governed by the equation

$$\frac{dN_\chi}{dt} = C_\odot - E_\odot N_\chi - A_\odot N_\chi^2$$

$$N_\chi = \left(\frac{C_\odot}{A_\odot}\right)^{1/2} \frac{\tanh\left(\kappa t_\odot/\tau\right)}{\kappa + \frac{1}{2} E_\odot \tau \tanh\left(\kappa t_\odot/\tau\right)}.$$



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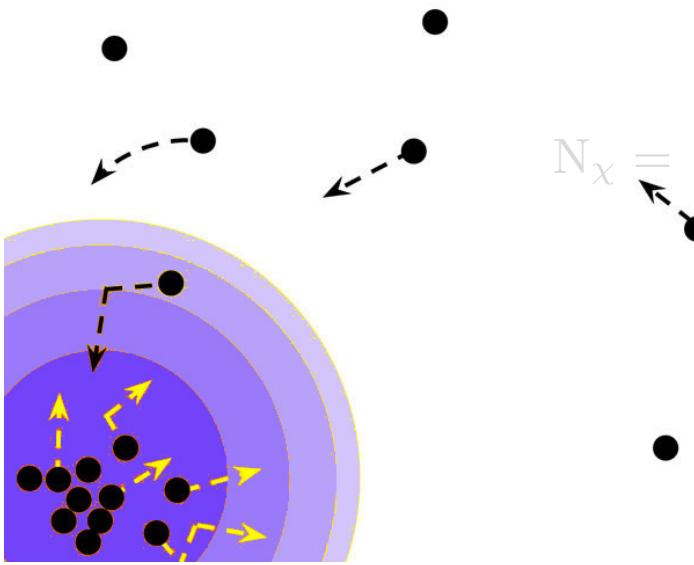

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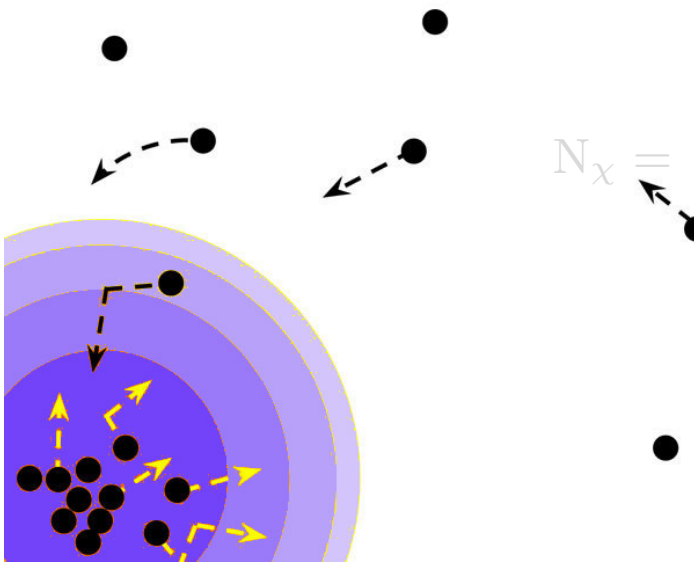

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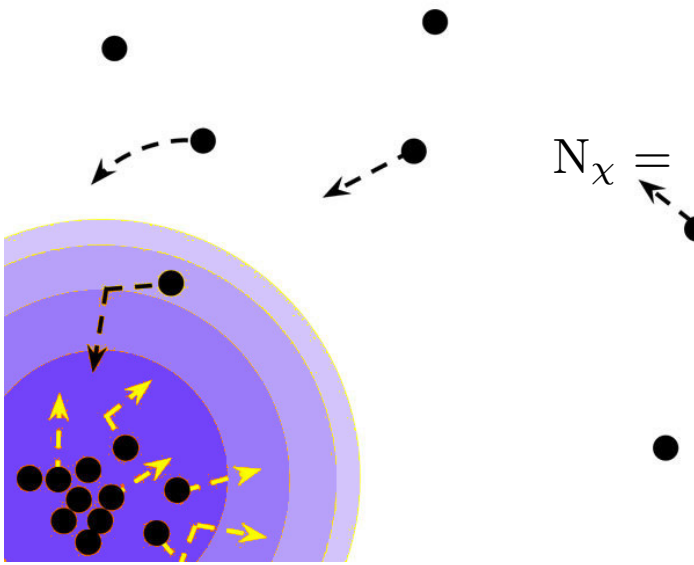

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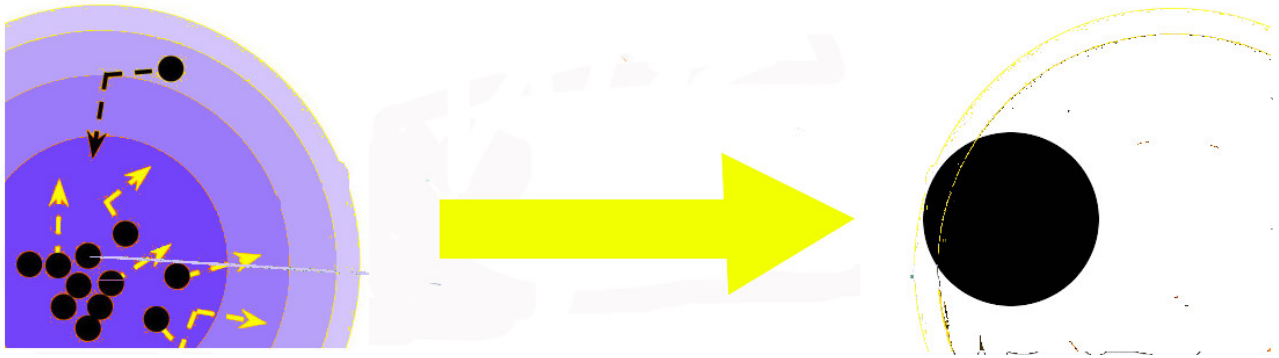
Introduction: Asymmetric DM

- Motivated by the fact that the DM and baryon densities are of the same order of magnitude. Nussinov '85, Kitano '05, Kaplan '09, Cohen '09, many more
- No annihilation implies (for DM masses above 10^{-8} GeV)

$$\mathrm{N}_\chi = C_\odot t_\odot.$$

- Formation of Black Holes when N_χ equals the Chandrasekhar limit.



Dark Matter in Neutron Stars: Capture

- We consider DM-neutron cross section of the form

$$\frac{\mathrm{d}\sigma(v_{\mathrm{rel}}, \cos\theta_{\mathrm{cm}})}{\mathrm{d}\cos\theta_{\mathrm{cm}}} = \frac{\sigma_{\chi-n}}{2}.$$

- The rate of DM accretion is

$$C_{\odot}^{w} = \int_0^{R_{\odot}} 4\pi r^2 \mathrm{d}r \int_0^{\infty} \mathrm{d}u \left(\frac{\rho_{\chi}}{m_{\chi}}\right) \frac{f_{\odot}(u)}{u} \omega(r) \int_0^{\nu_e} R^{-}(\omega \to \nu)\mathrm{d}\nu,$$

with

$$R^{\pm}(\omega \to v) = 16\,\mu_{+}^{4} n(r) N_{fd} \frac{v}{w} \int_0^{\infty} \mathrm{d}s \int_0^{\infty} \mathrm{d}t\, t\, f_2(u)(1 - f_4(u')) \frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta_{cm}} H^{\pm}(s, t, \omega, v).$$

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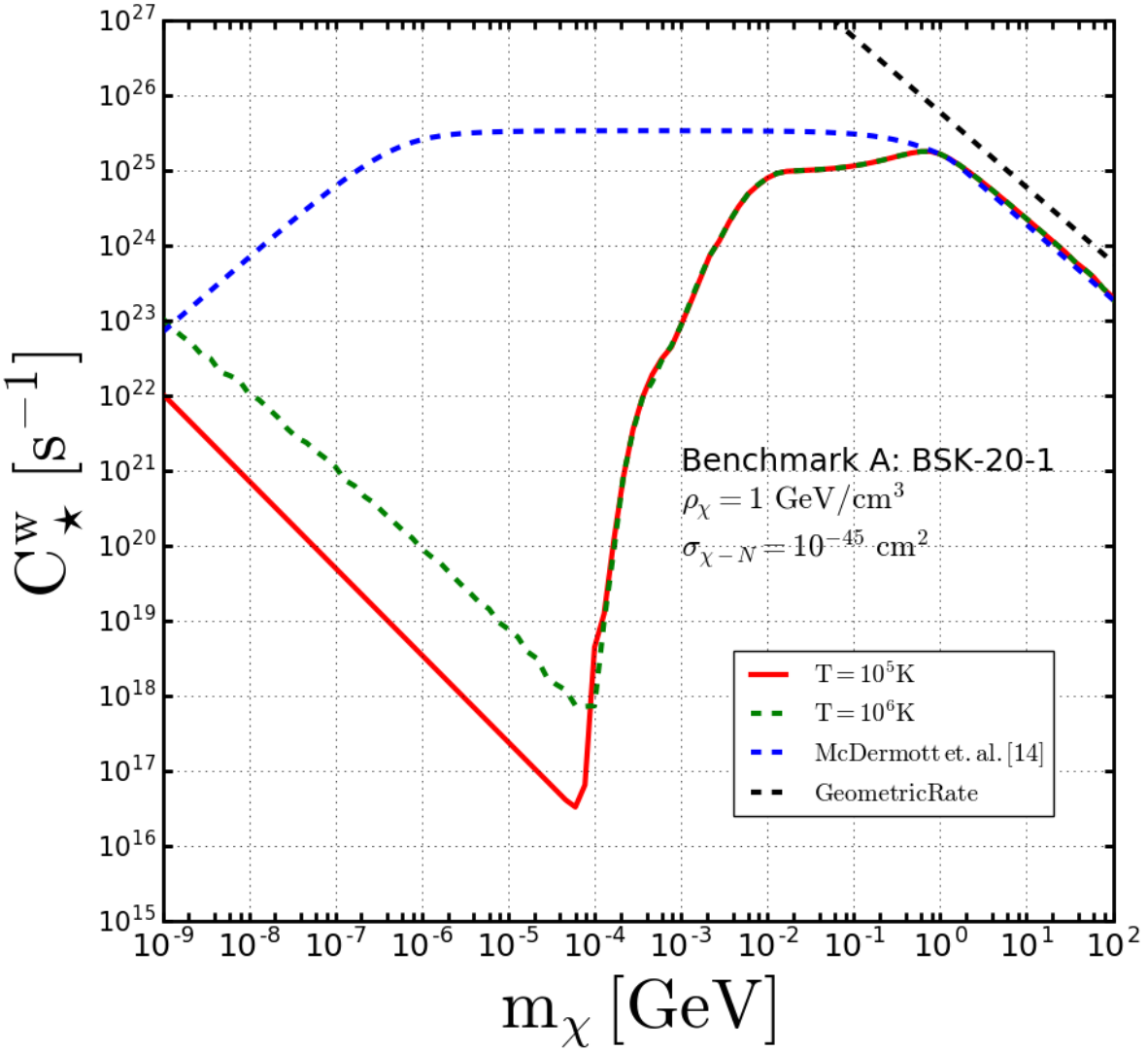
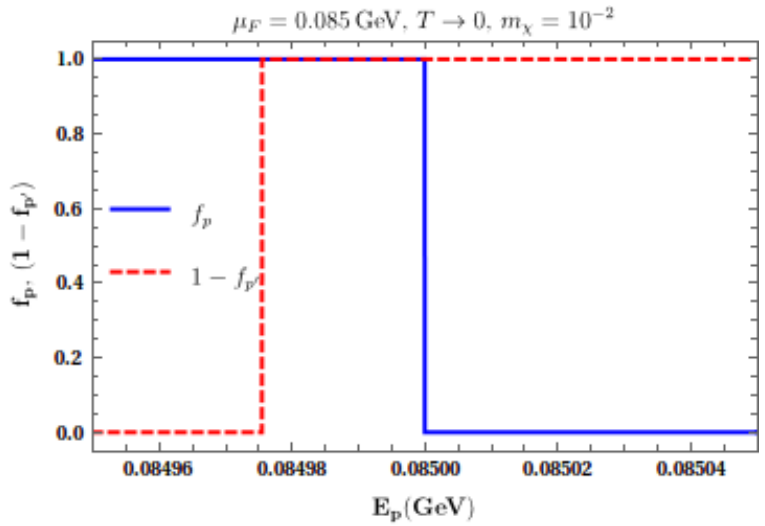
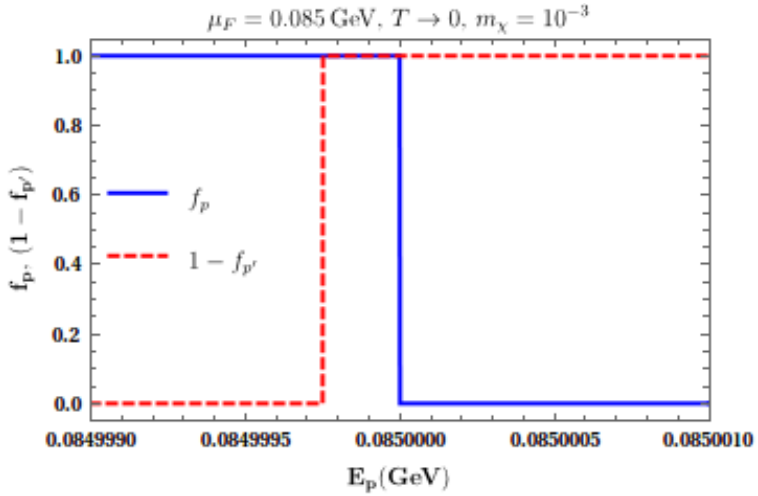
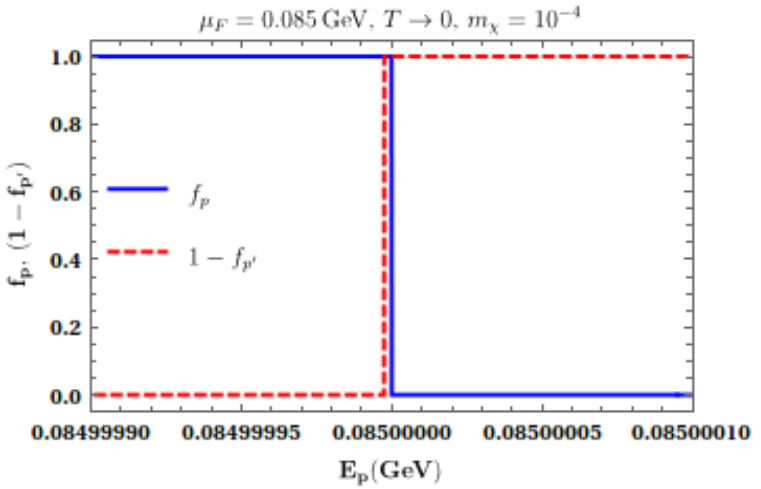
Capture Rate for Const. $\sigma_{\chi n}$



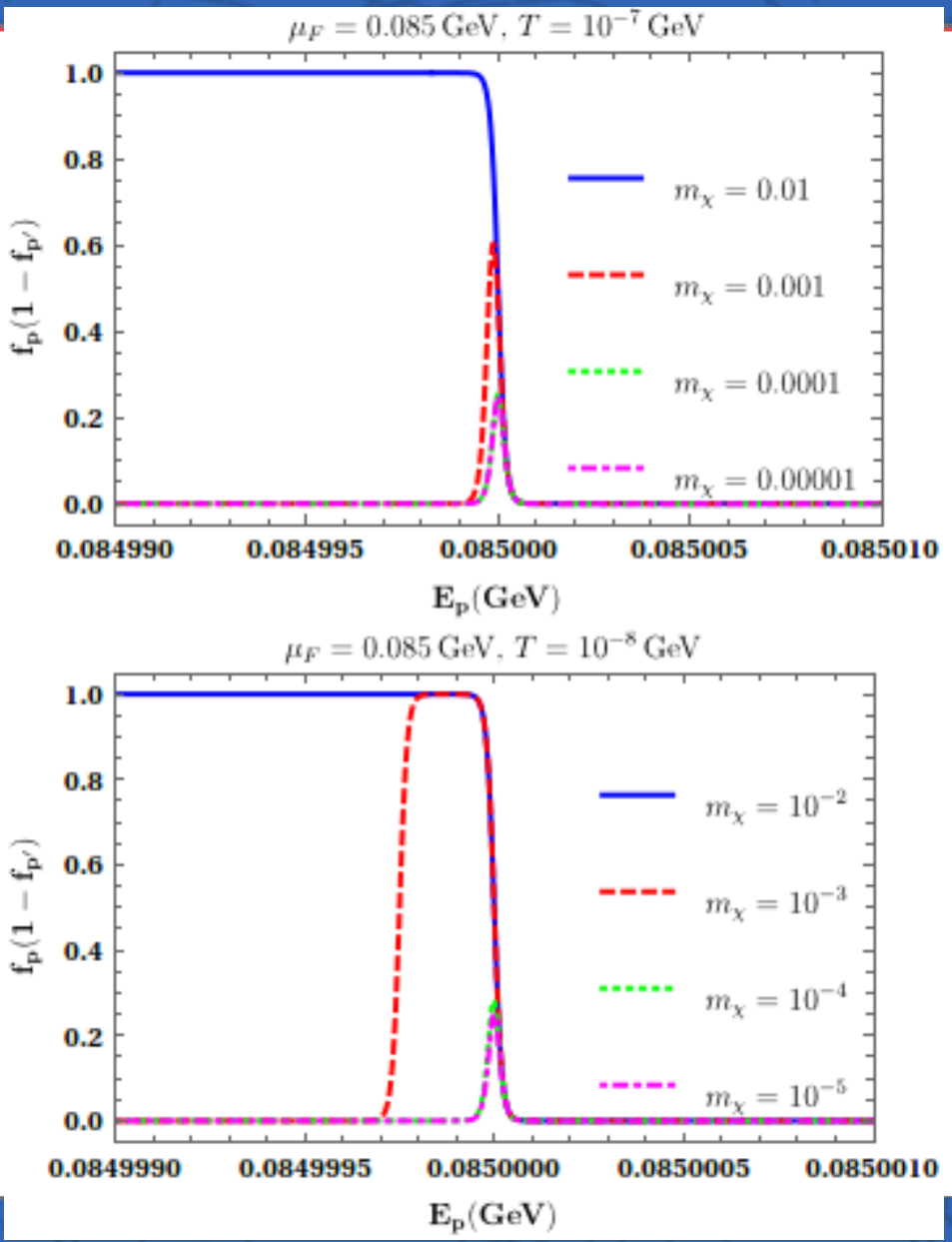
Scattering off Degenerate Neutrons: $T \to 0$







Scattering off Degenerate Neutrons: T $\neq$ 0



Constraining Dark Matter-Neutron Cross Section with Neutron Stars

- Chandrashekar Limit (for bosons):

$$N_{\rm ch}^{\rm bosons} \simeq 1.5 \times 10^{34} \left(\frac{100{\rm GeV}}{m_{DM}}\right)^2$$

- Self Gravitation:

$$N^{\rm self} \simeq 4.8 \times 10^{41} \left(\frac{100{\rm GeV}}{m_{DM}}\right)^{5/2} \left(\frac{T_{NS}}{10^5{\rm K}}\right)^{3/2}$$

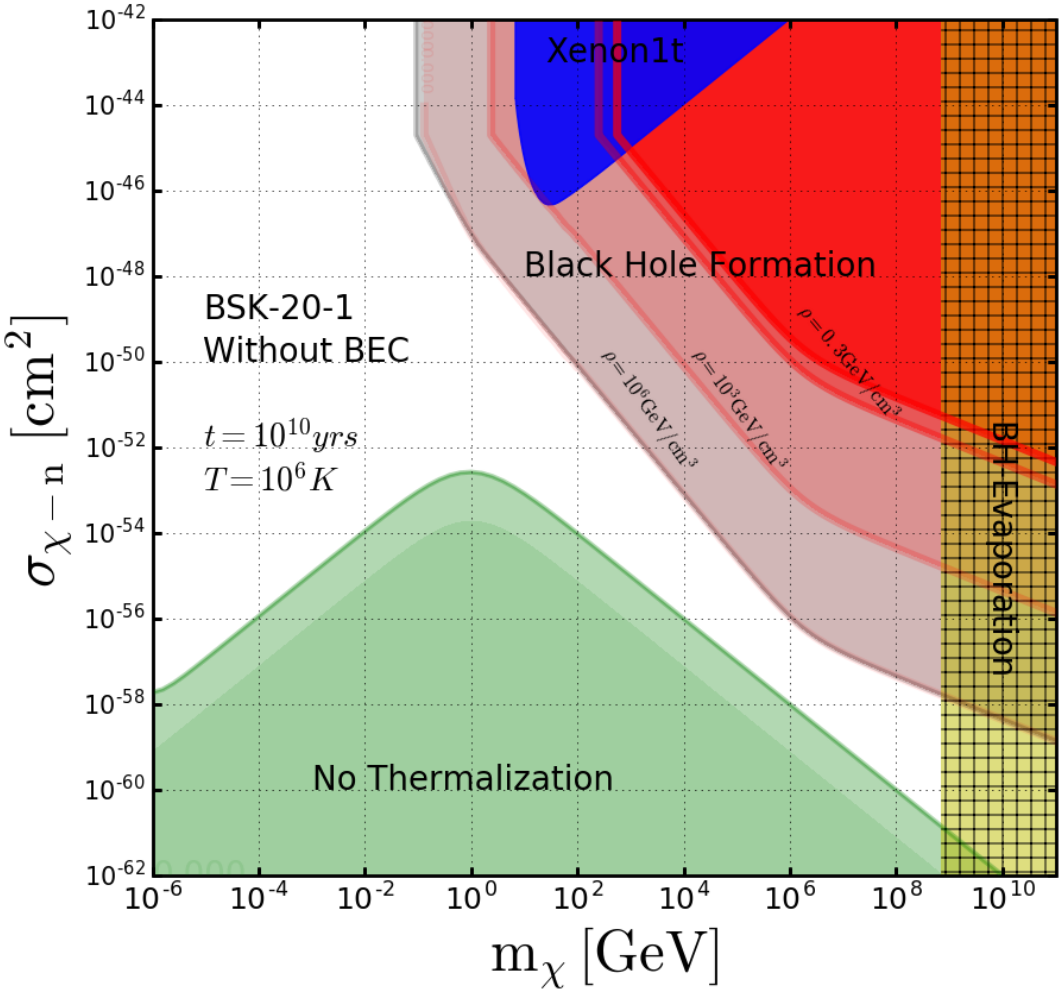
- Condition for Black Hole with BEC formation:

$$N^{BEC} \simeq 1.5 \times 10^{34} \left(\frac{100{\rm GeV}}{m_{DM}}\right)^2 + 10^{36} \left(\frac{T_{NS}}{10^5{\rm K}}\right)^3 .$$

McDermott '12, Kouvaris '10 '11 '12, Bell '12, Bramante '13....

New Constraints on Asymmetric Dark Matter (Bosons)

RG, Y.Genolini and T. Hambye (in preparation)



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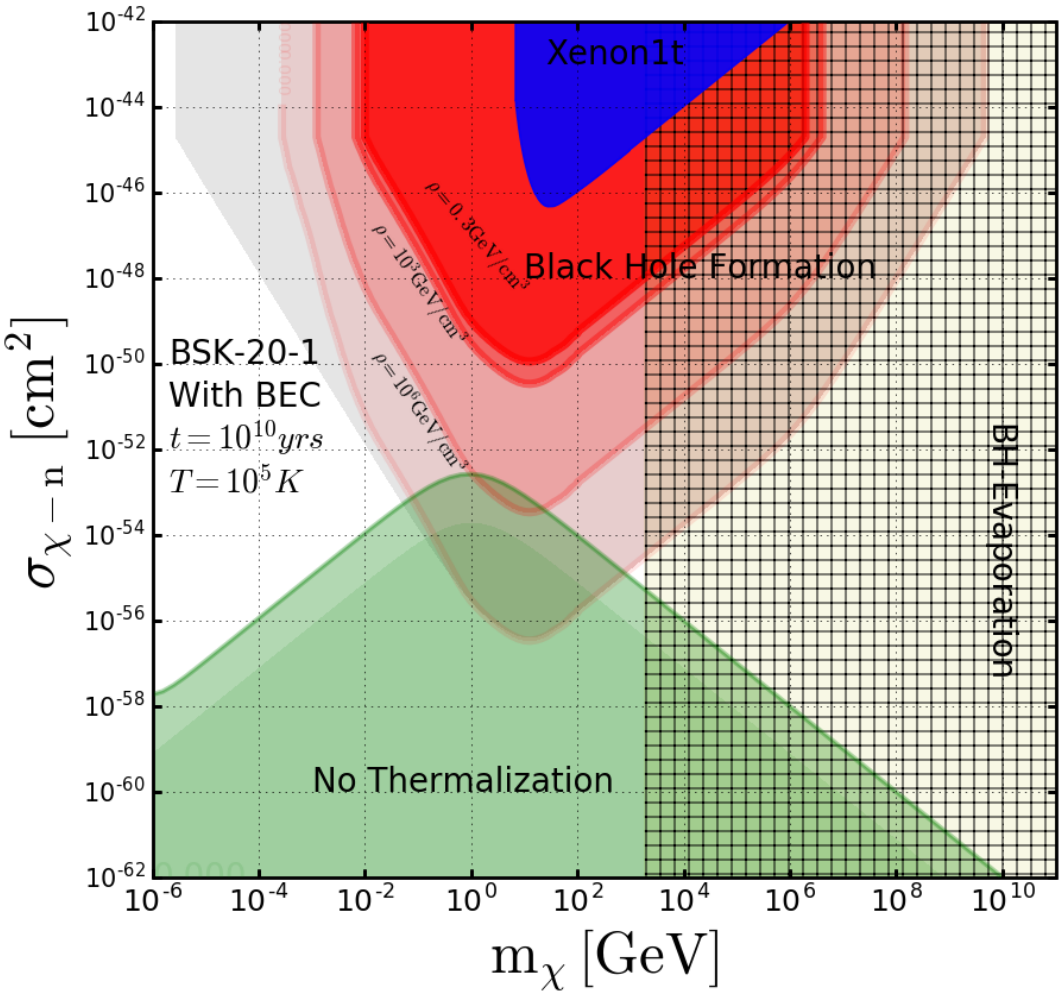

Conclusions and Outlook

- Considered realistic Neutron Star profile and re-evaluated DM accretion for arbitrary degeneracy with Pauli blocking.
- Strong constraints on DM-Neutron interactions can be derived. We show that constraints on DM-Neutron cross section is weaker than that in literature for DM $< 1\mathrm{GeV}$.

Thank You !