

# Particle Physics with Neutron Stars

Joachim Kopp (CERN & JGU Mainz)  
Rencontres de Moriond 2023



JOHANNES GUTENBERG  
UNIVERSITÄT MAINZ



# Neutron Stars

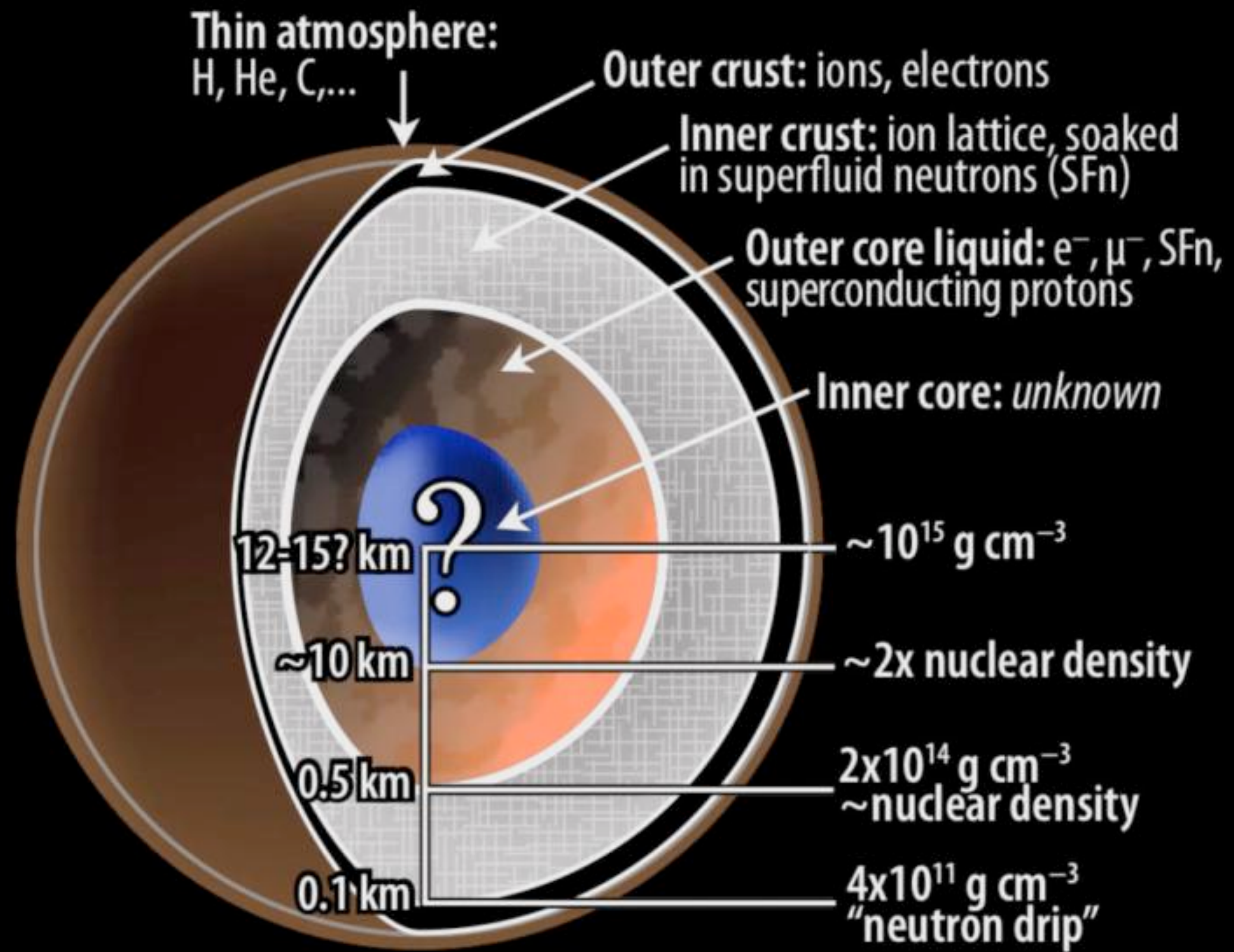
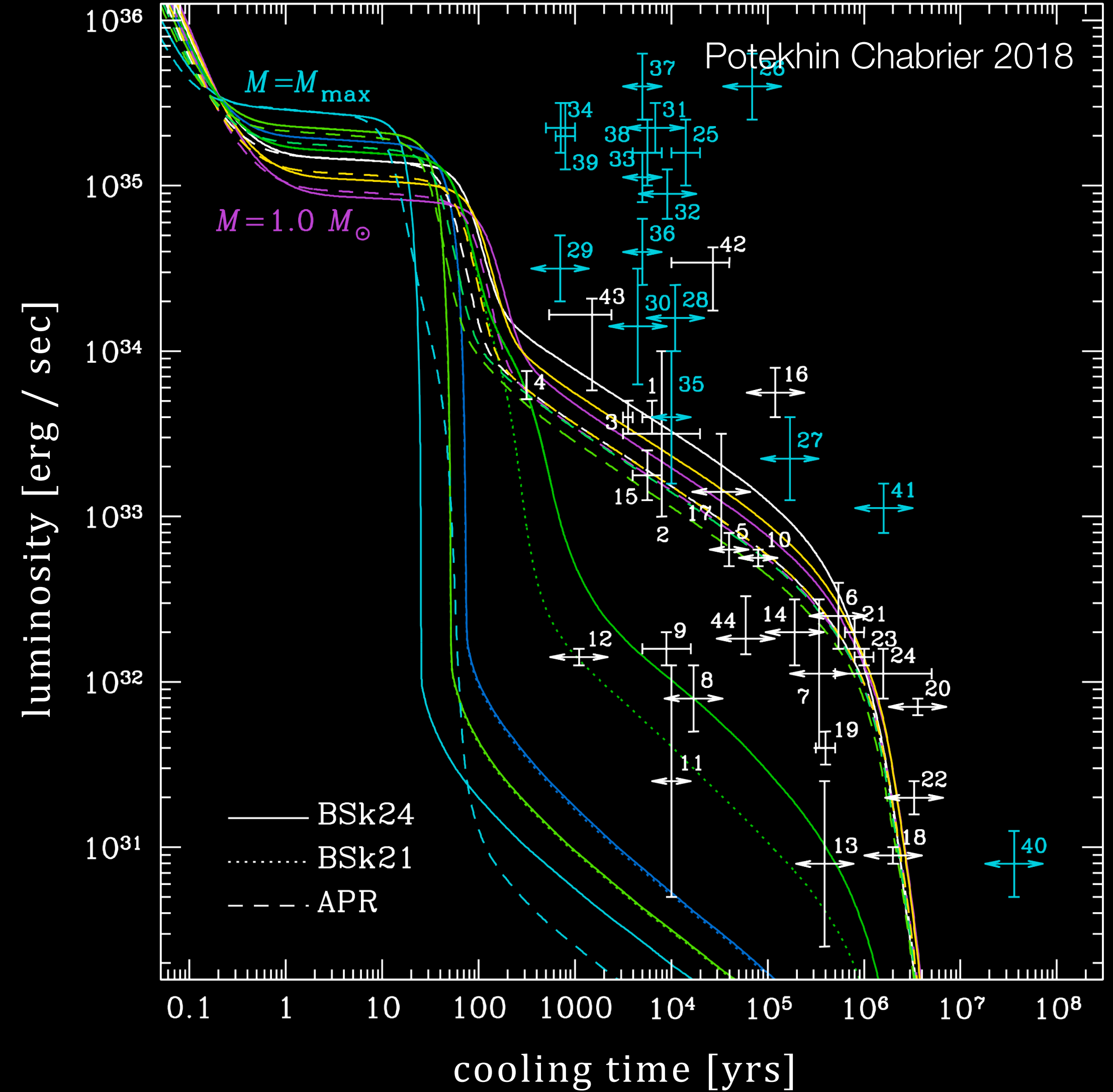
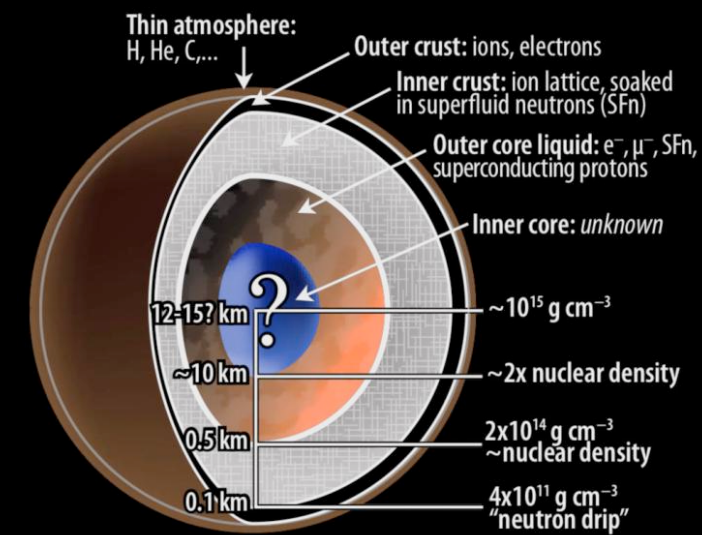


Image: Gendreau *et al.*

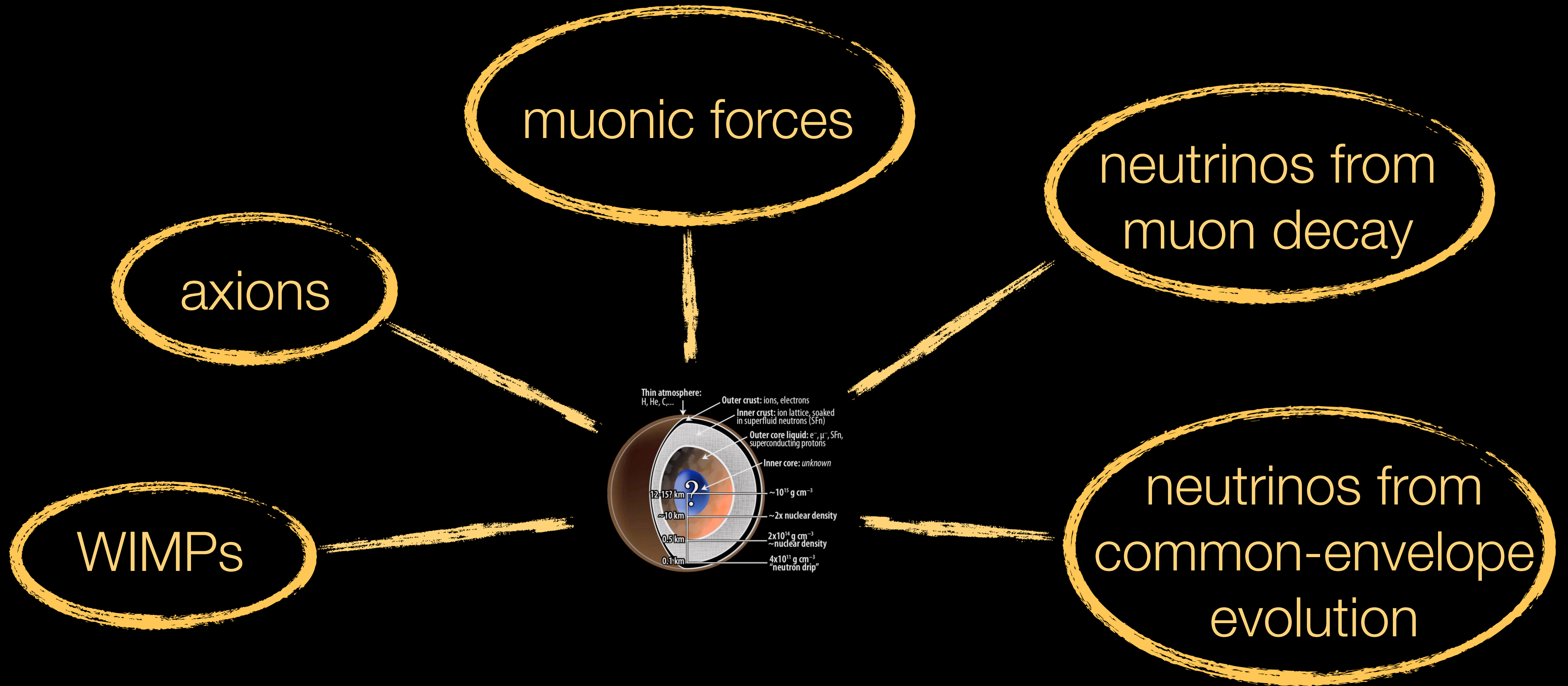


# Opportunities for Particle Physics





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# Dark Matter Accumulation in Neutron Stars

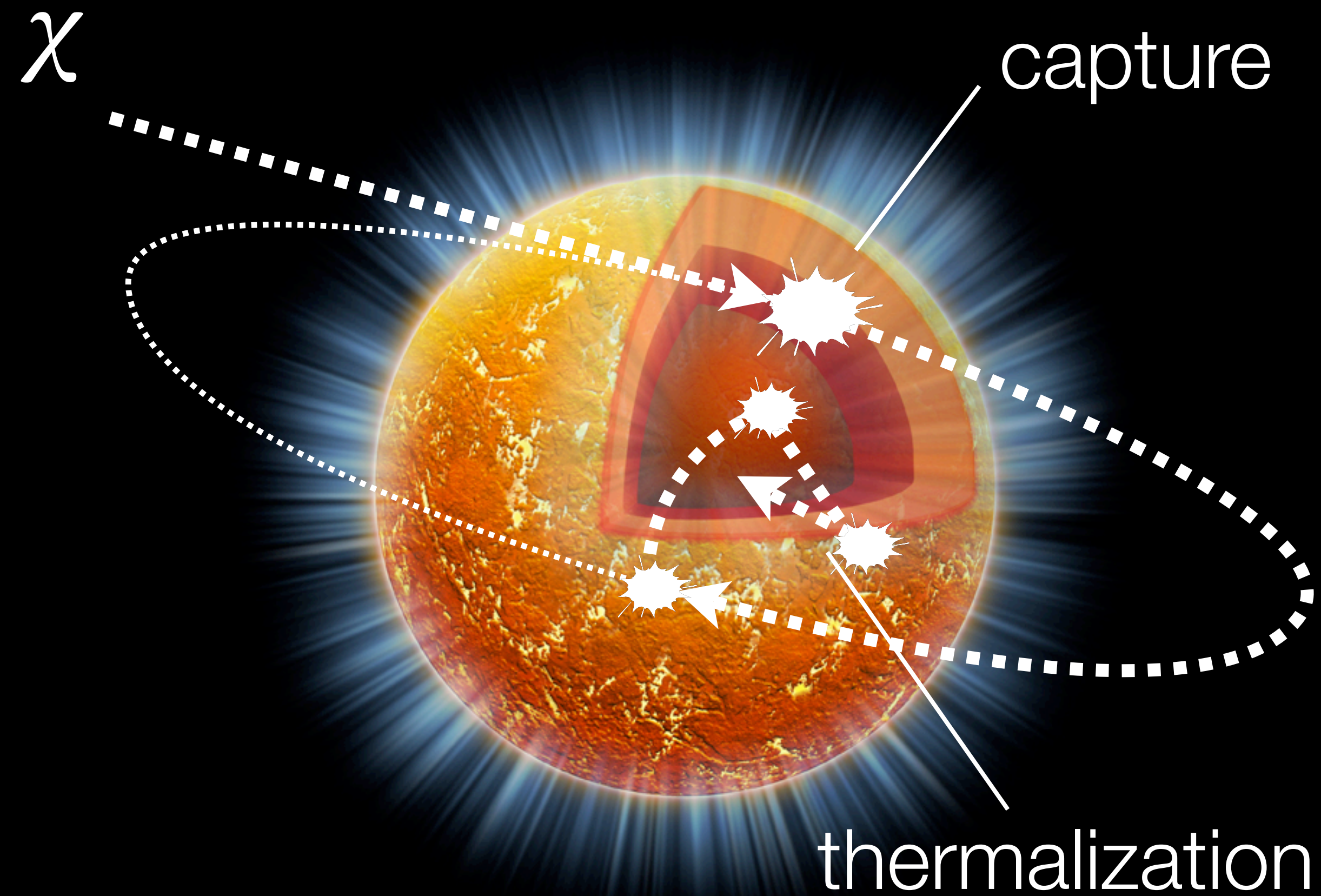
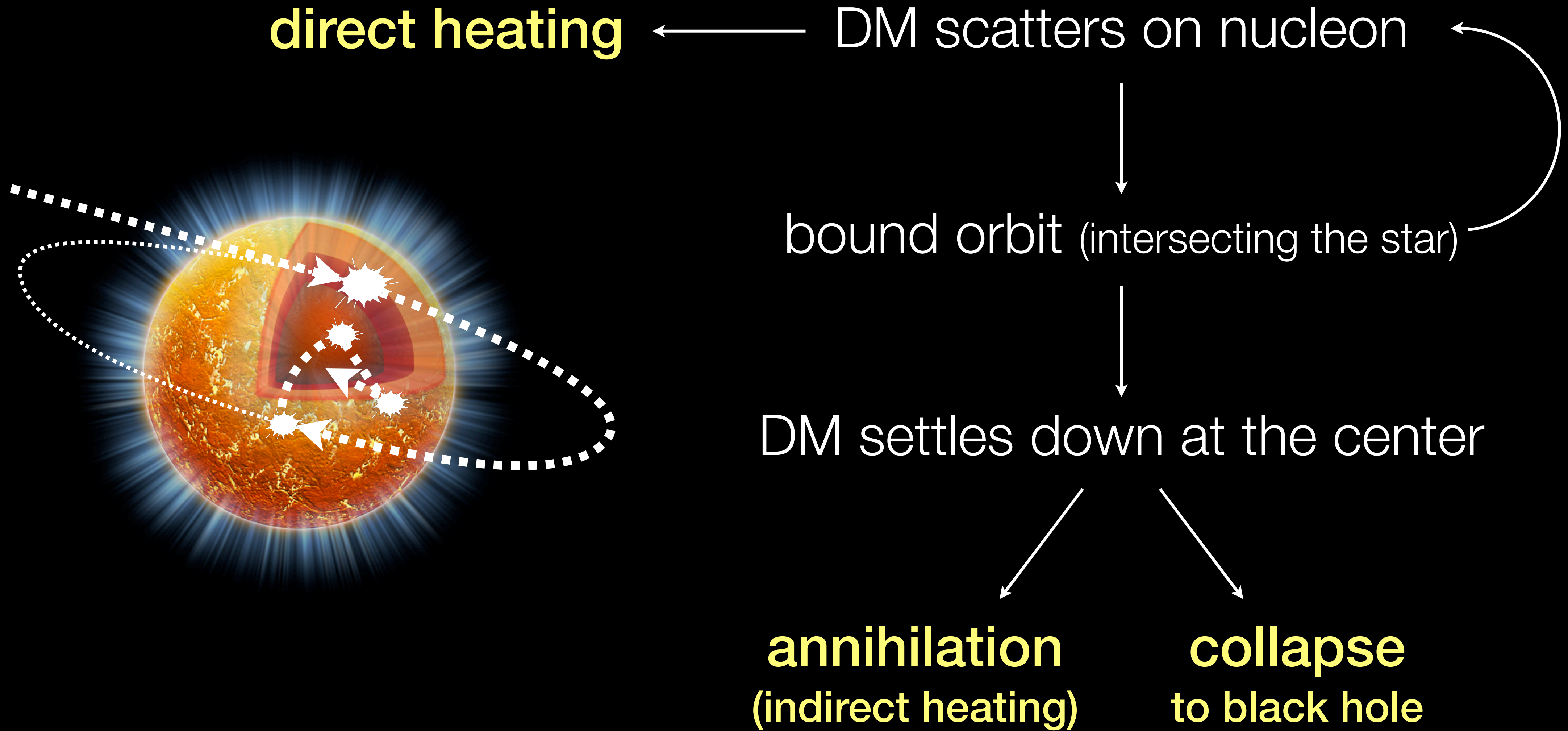


Image: NASA / Chandra / Hubble



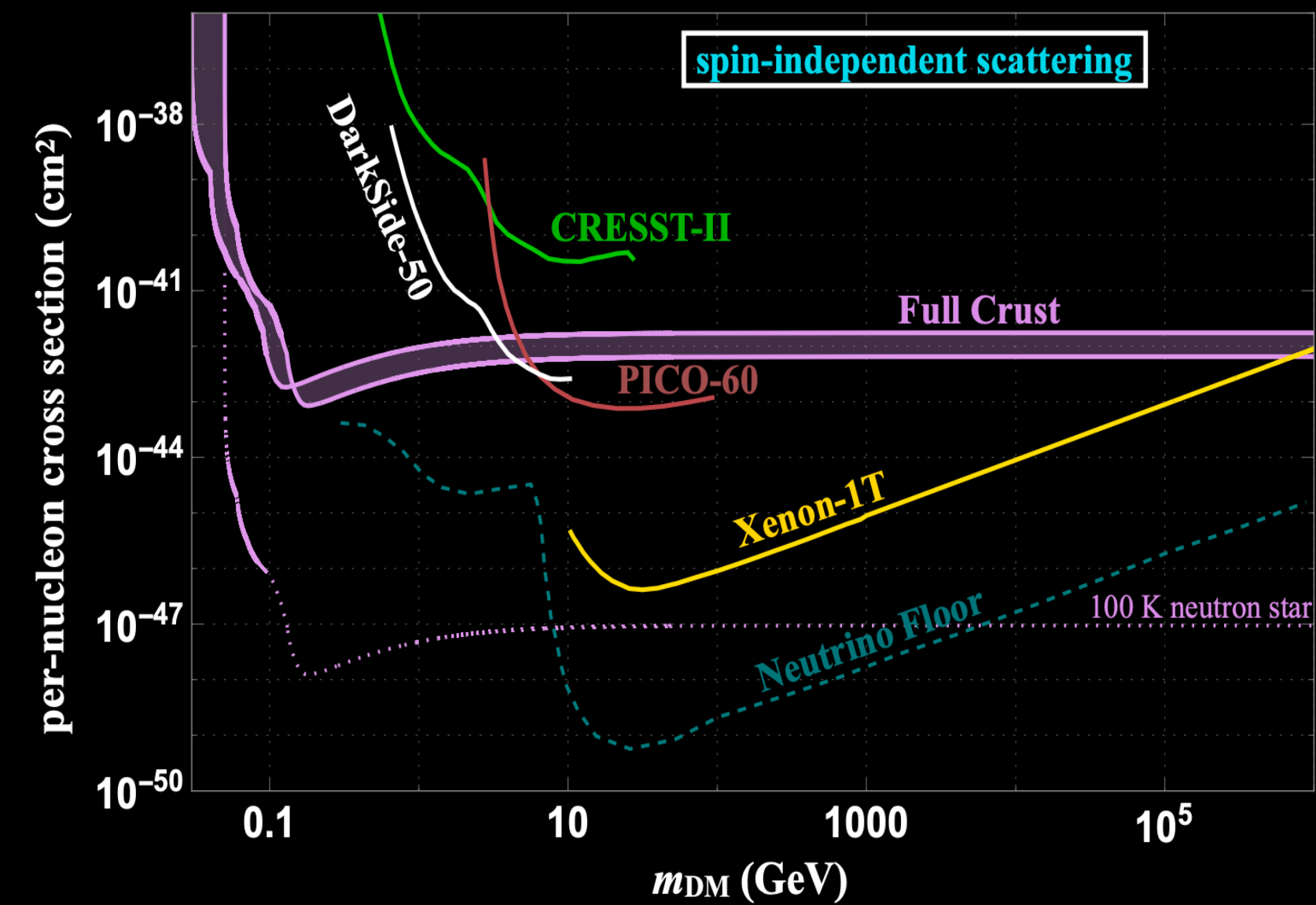
# Dark Matter Accumulation in Neutron Stars





# annihilation

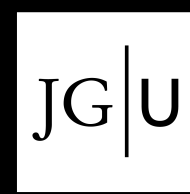
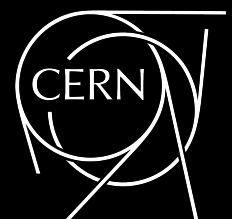
*Idea:*  
existence of cold neutron stars  
rules out anomalous heating



Acevedo Bramante Leane Raj [1911.06334](#)

# direct heating

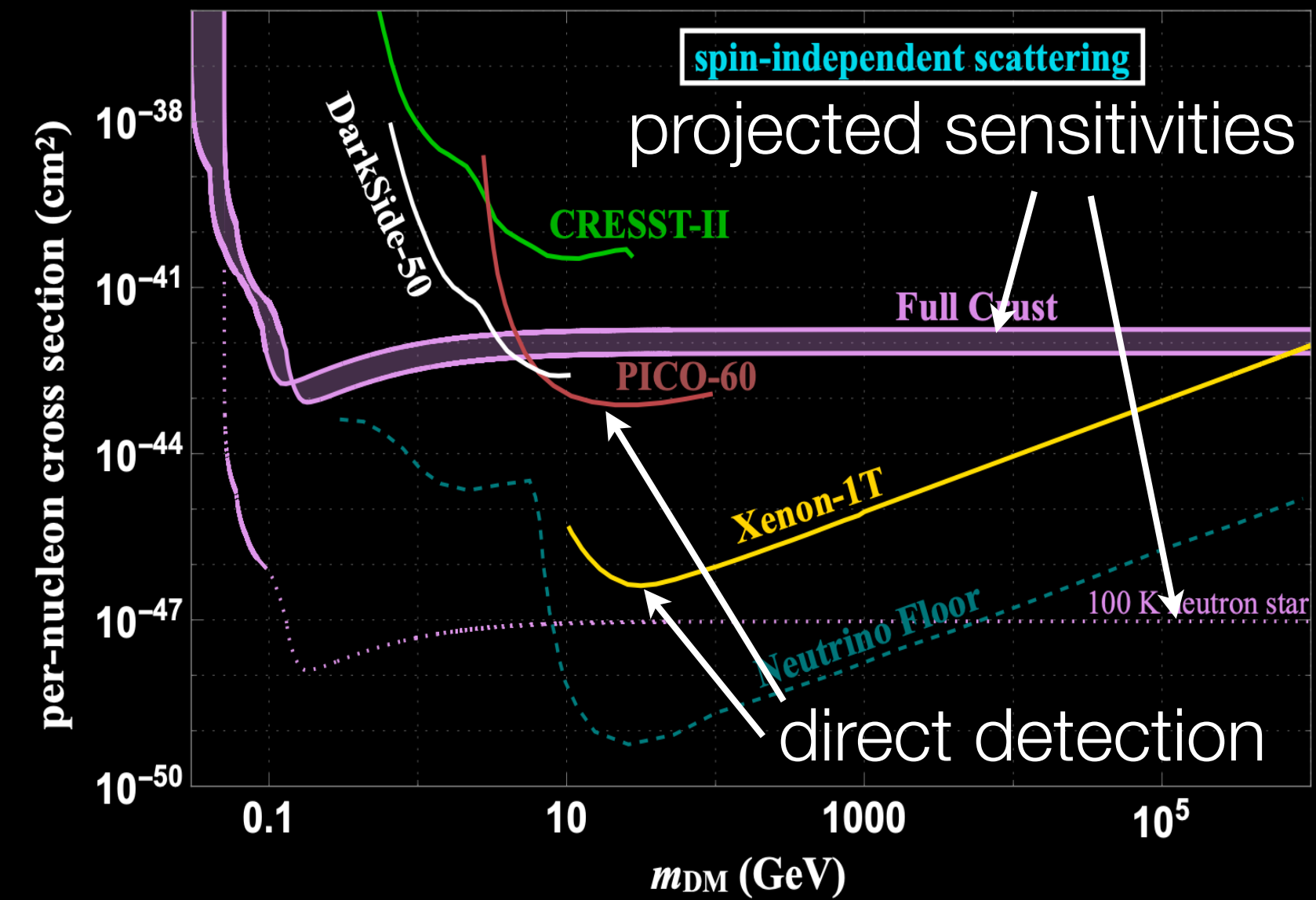
# collapse





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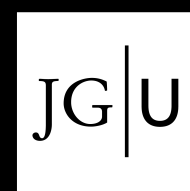
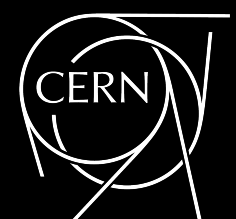
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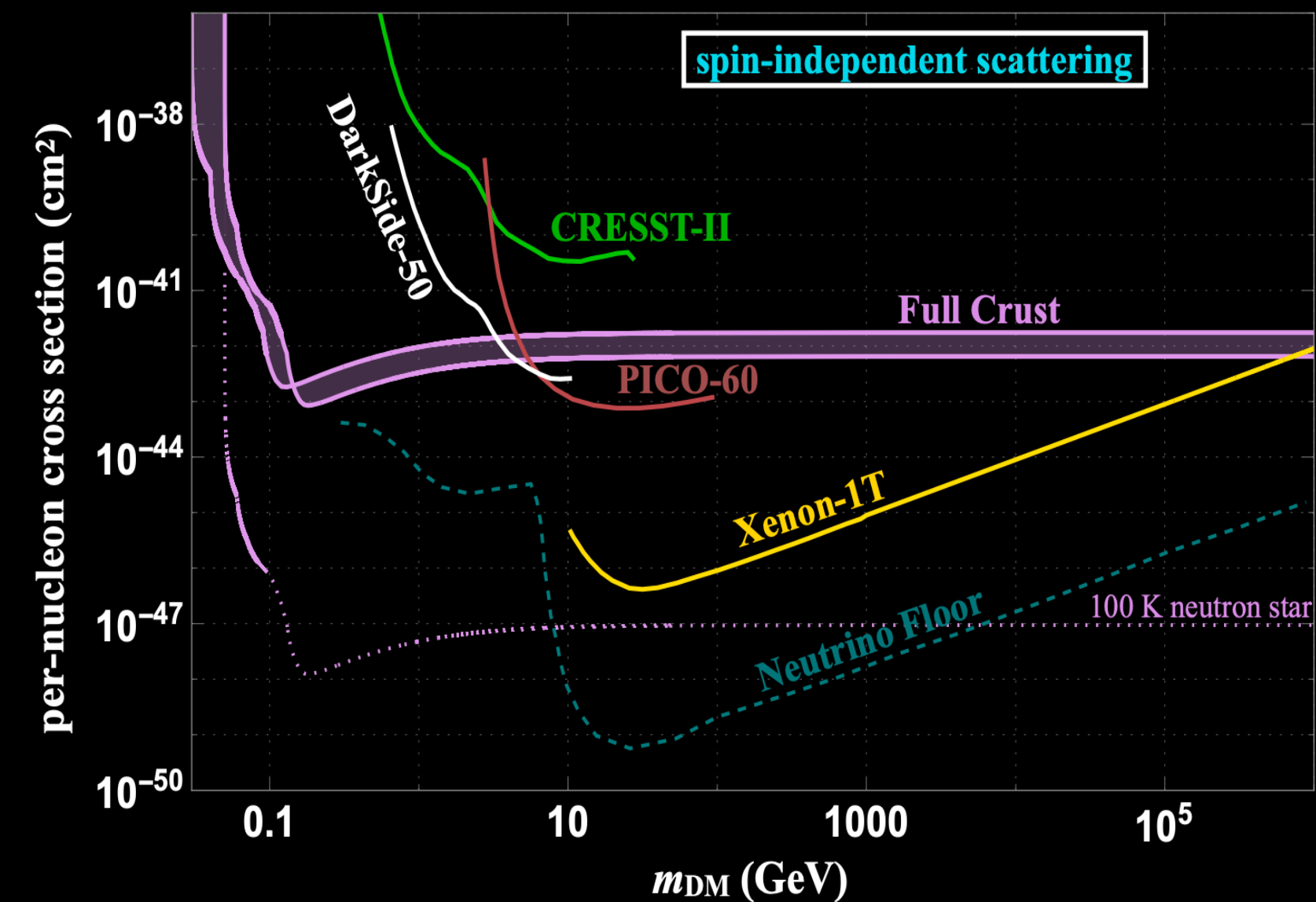
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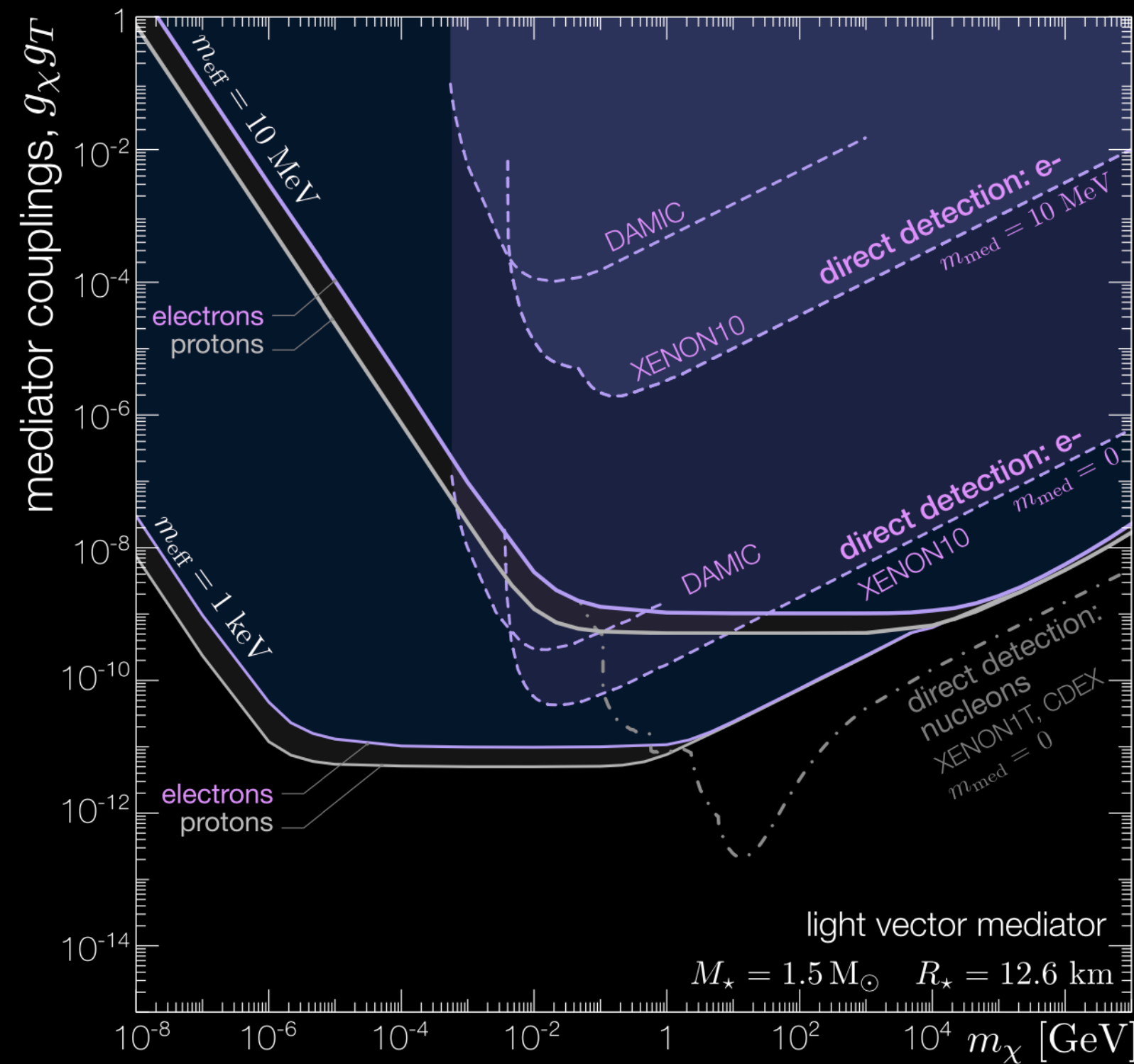
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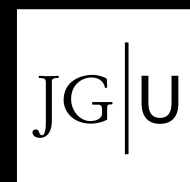
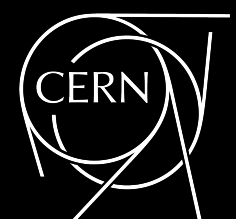
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Joglekar Raj Tanedo Yu [1911.13293](#)

see also other works by Joglekar Raj Tanedo Yu  
Baryakhtar Bramante Li Linden Raj  
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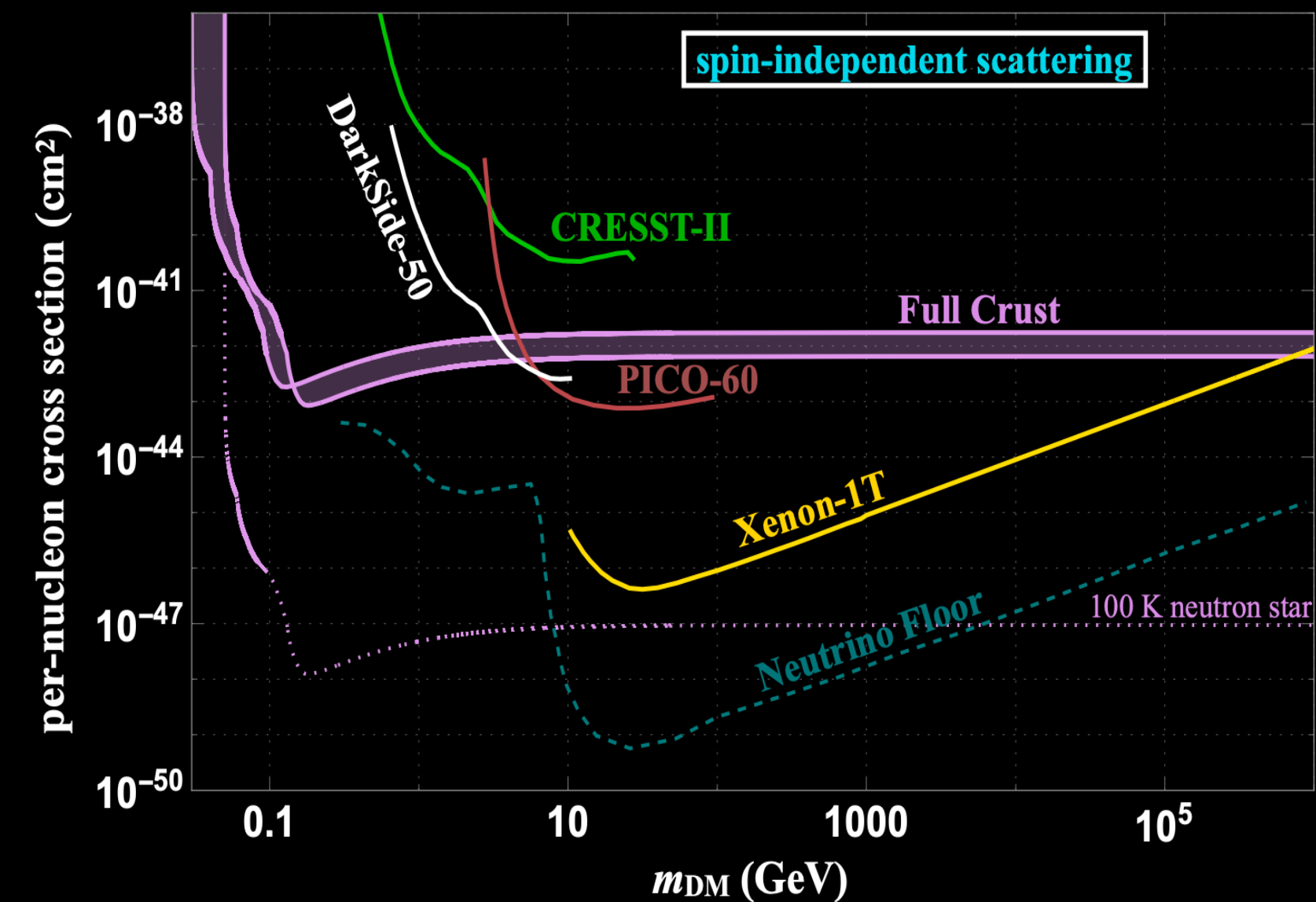
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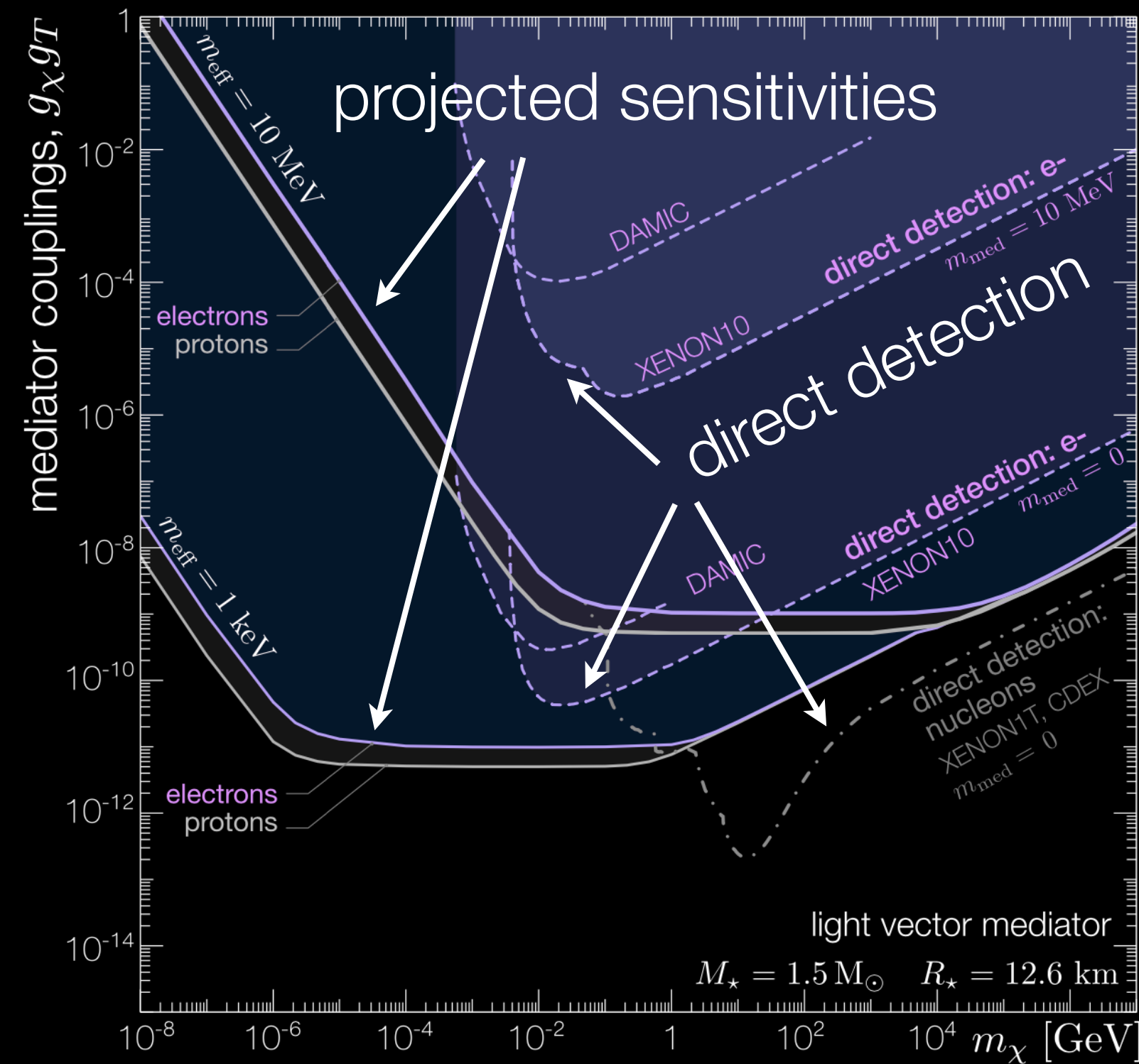
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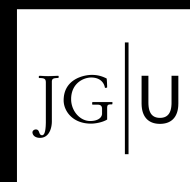
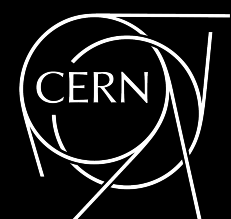
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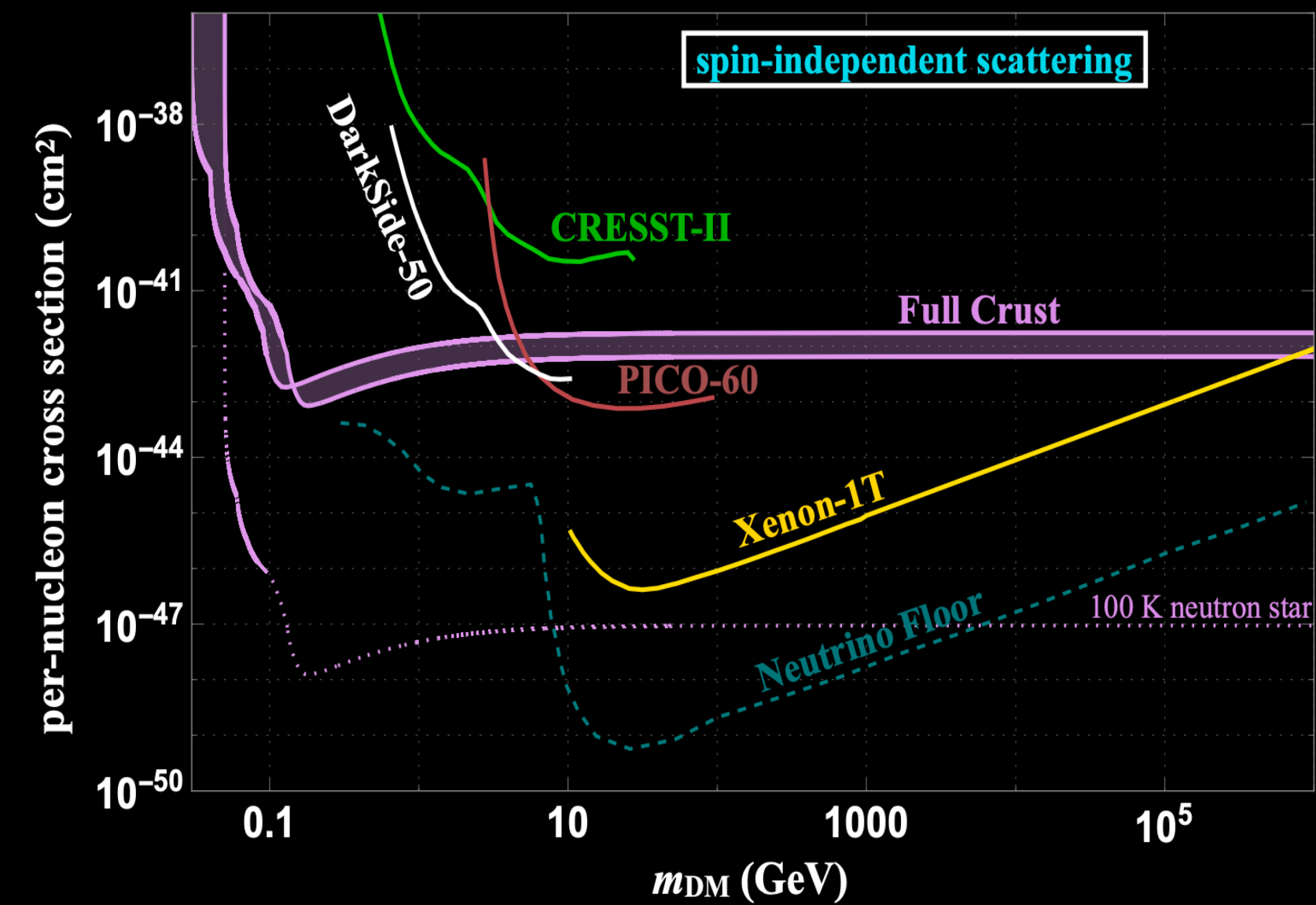
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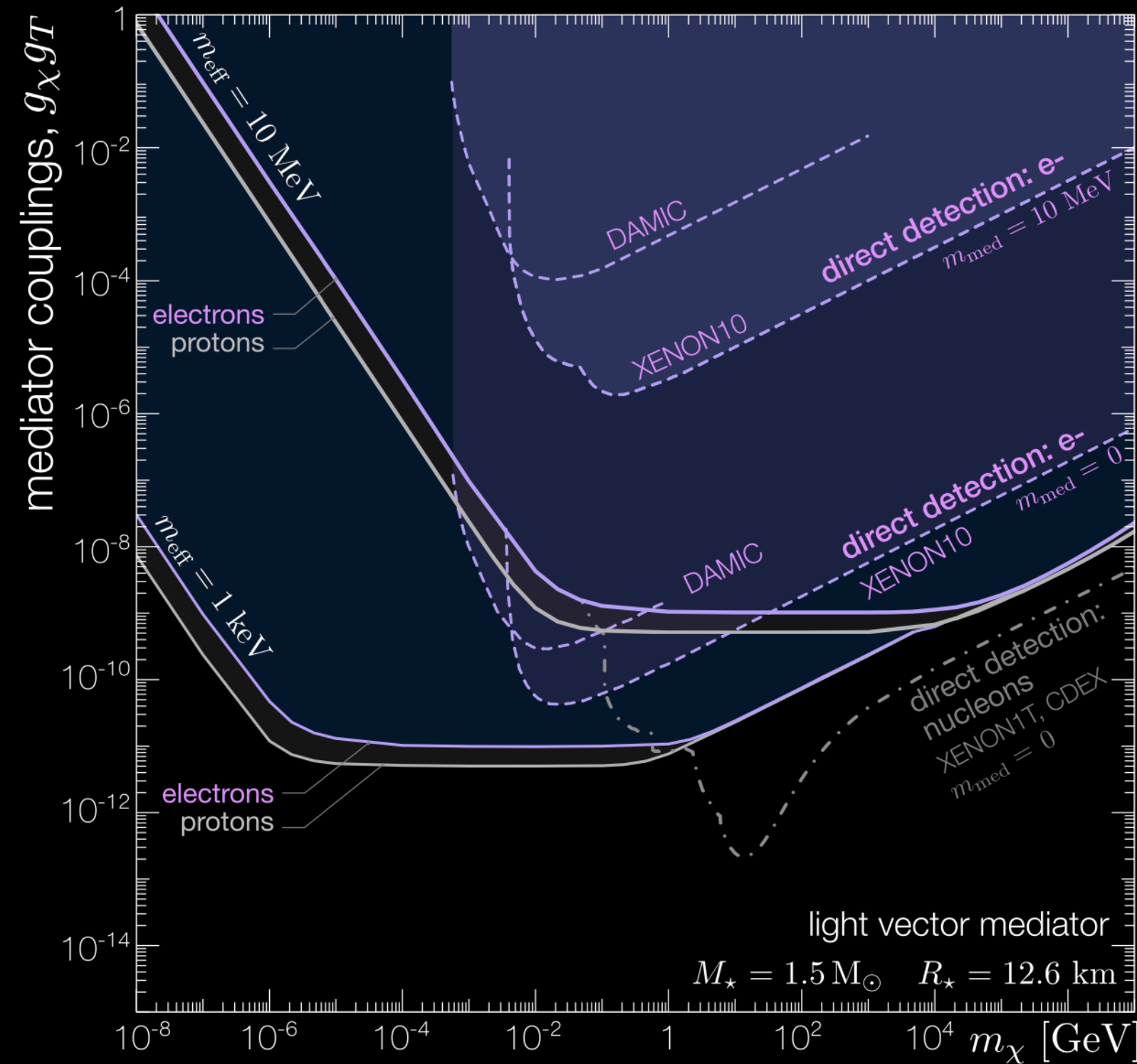
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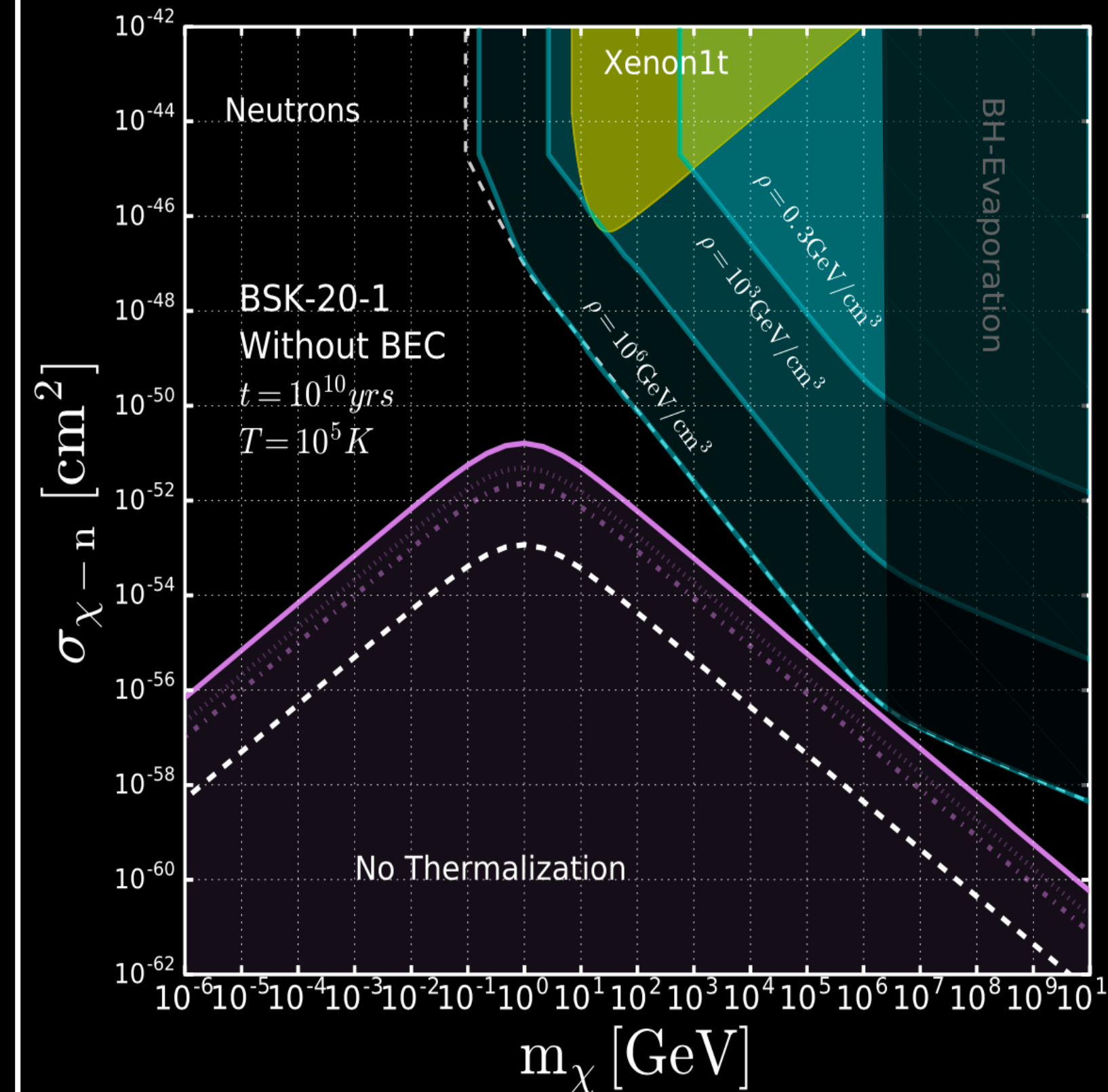
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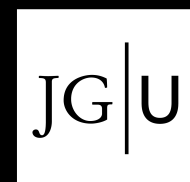
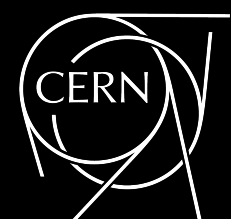


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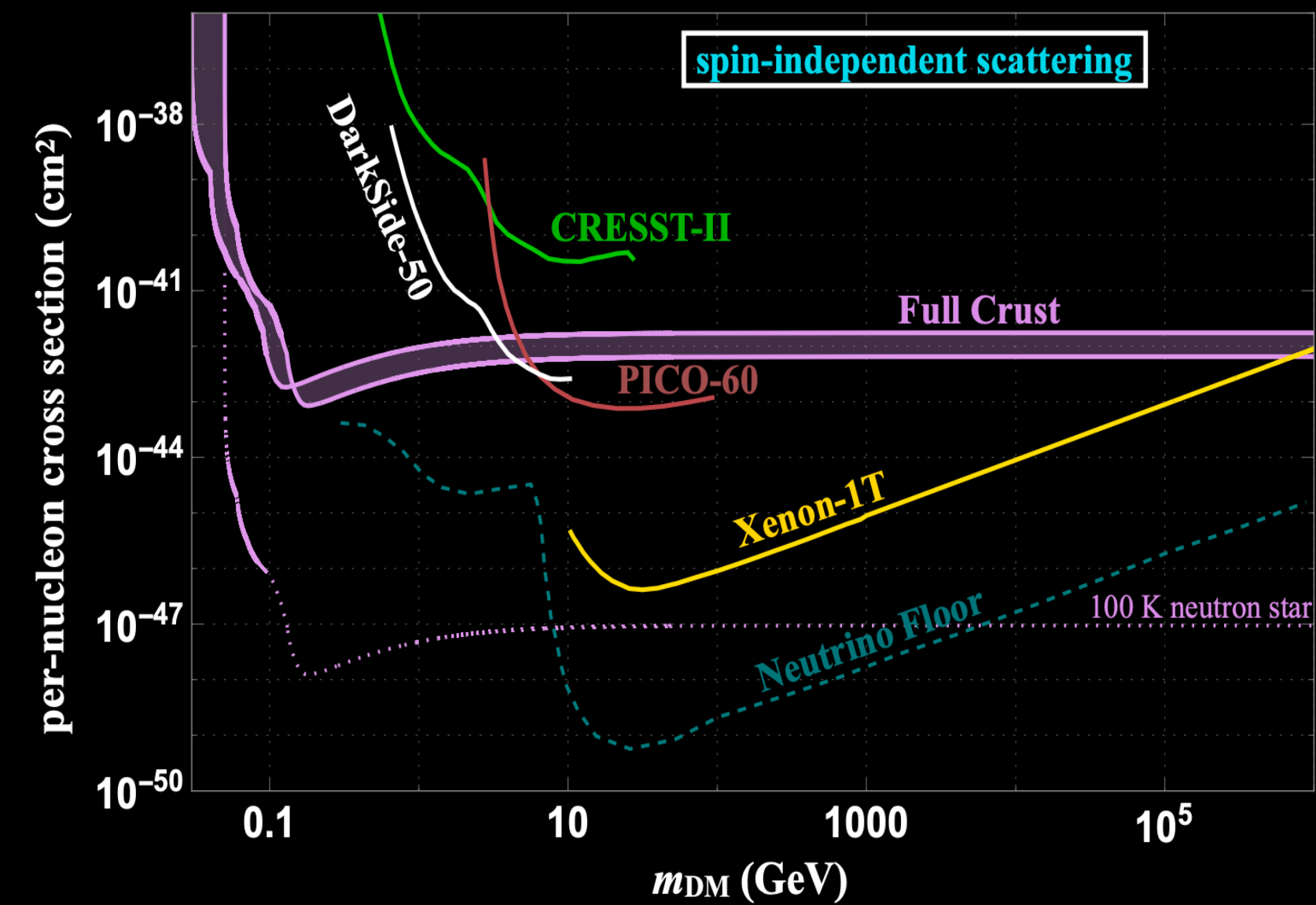
Garani Genolini Hambye [1812.08773](#)  
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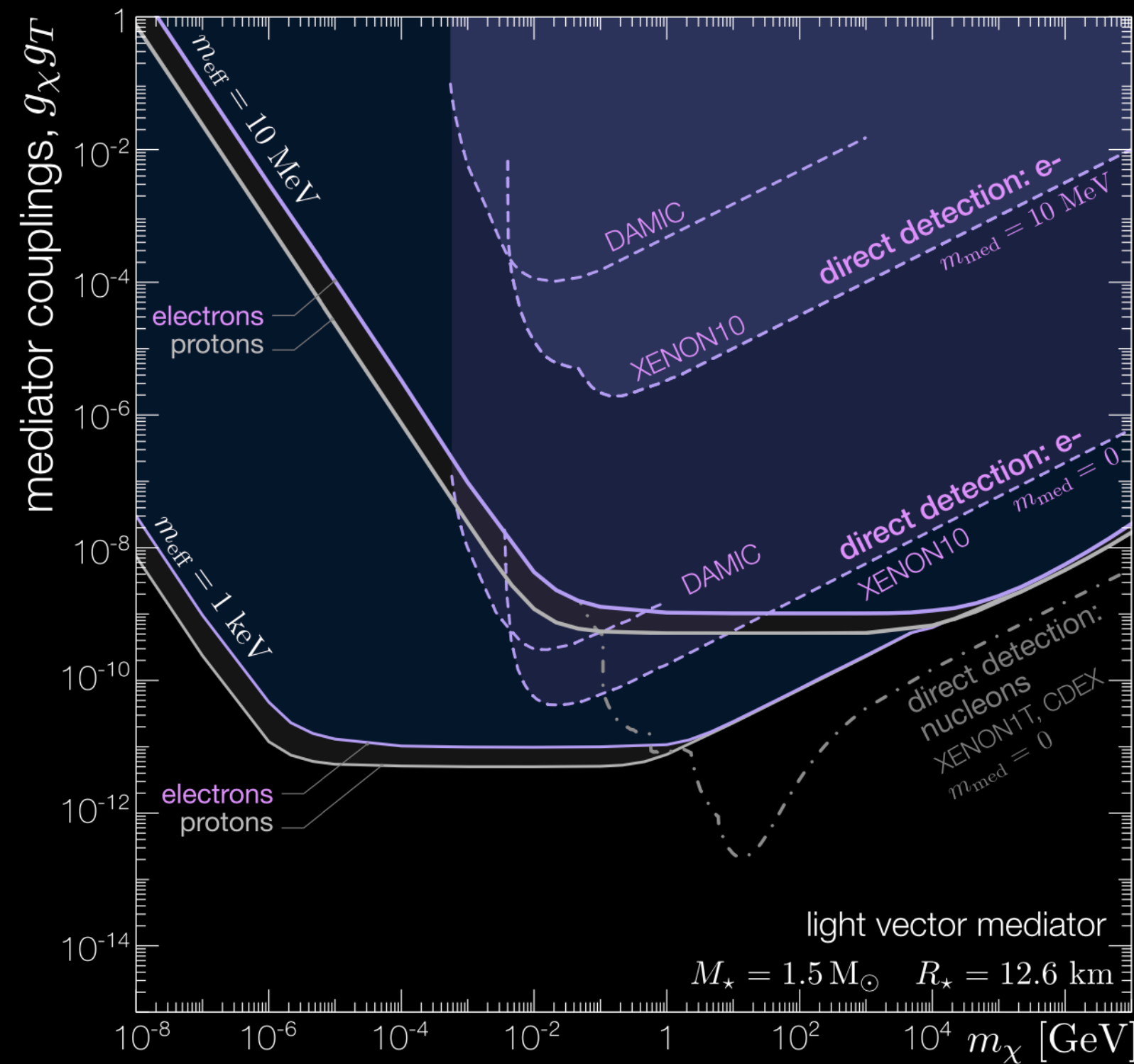
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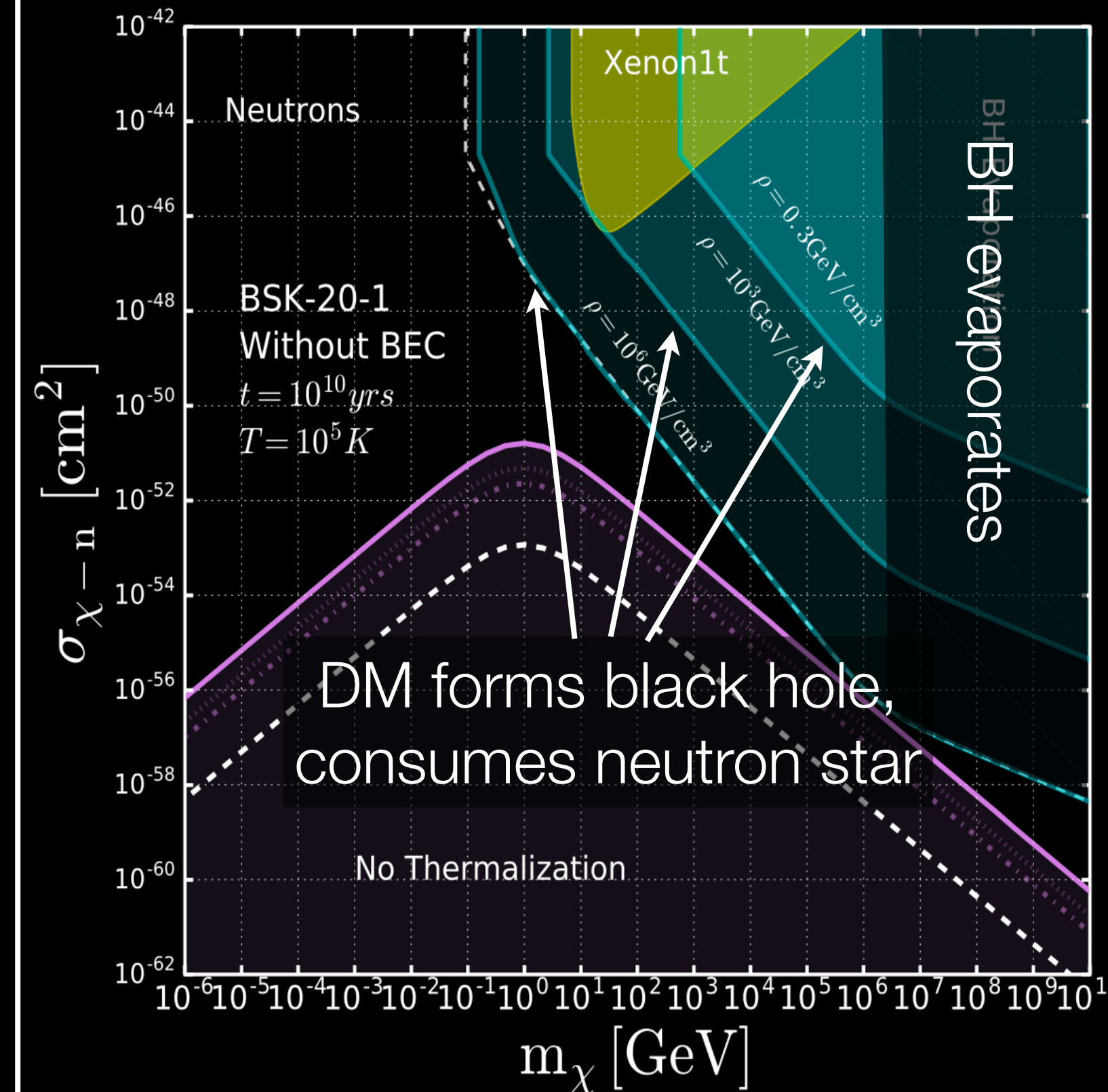
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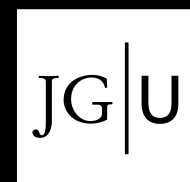
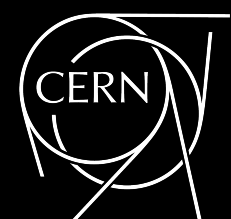
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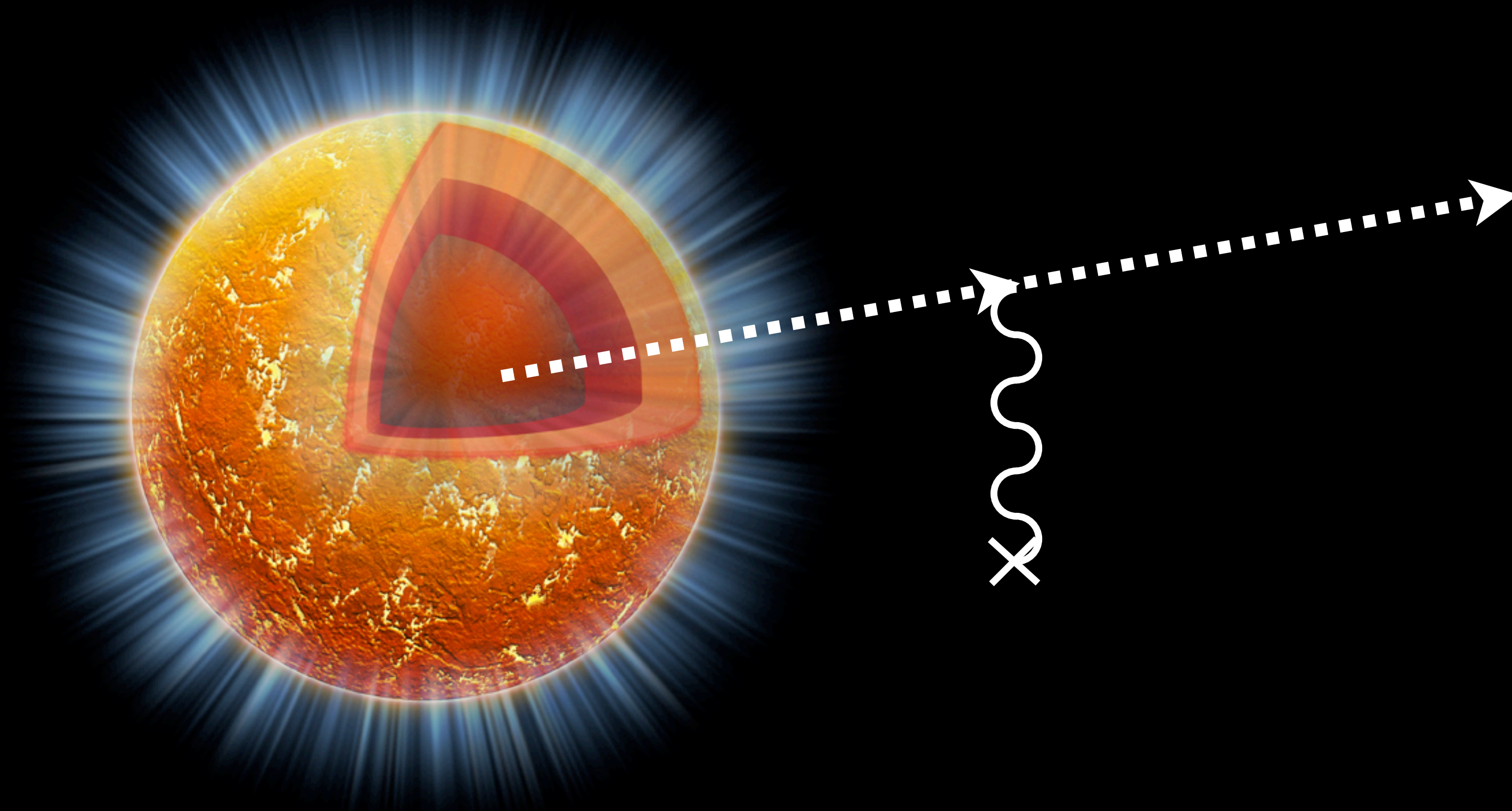


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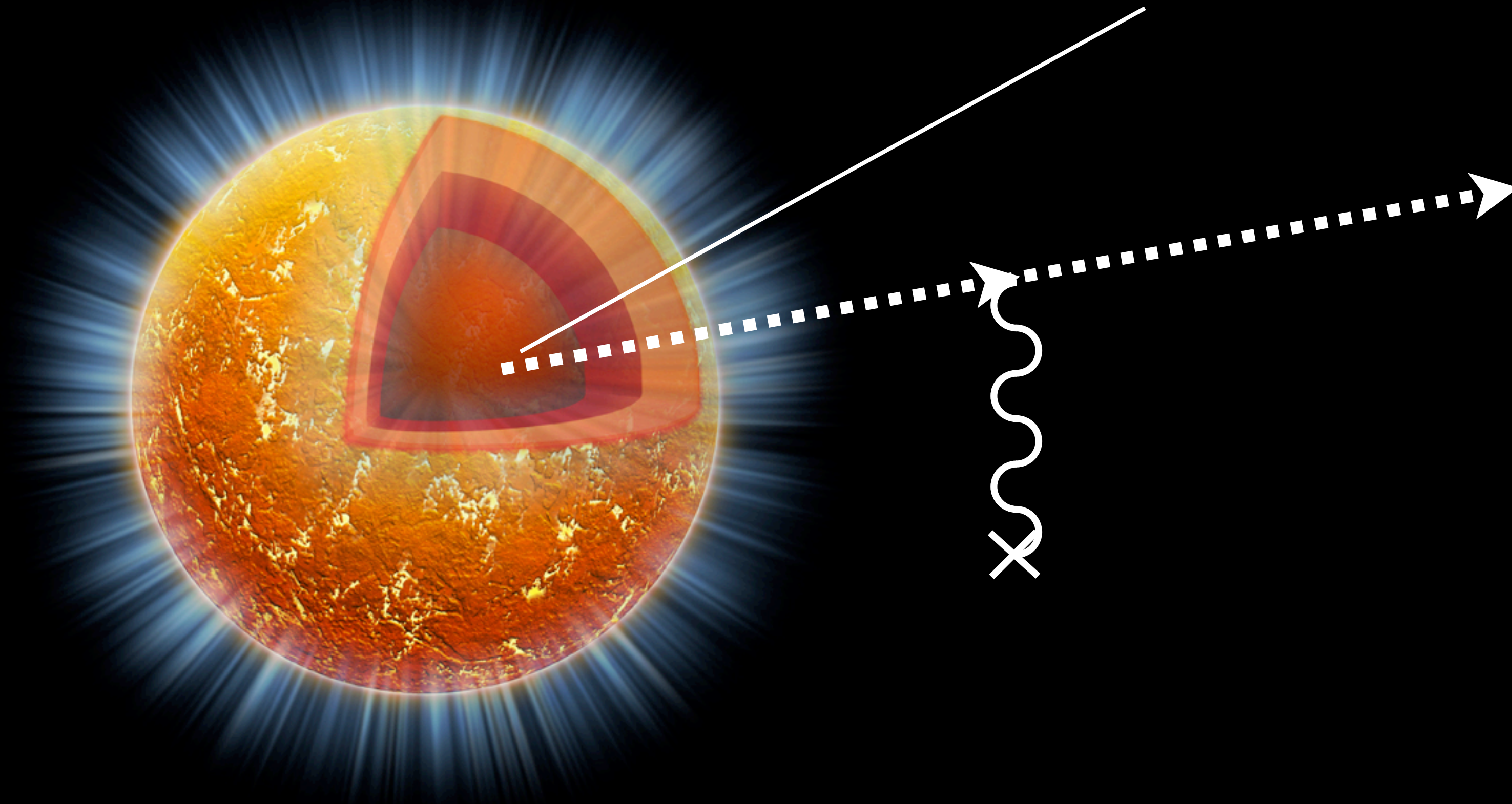
# Axions in Neutron Stars





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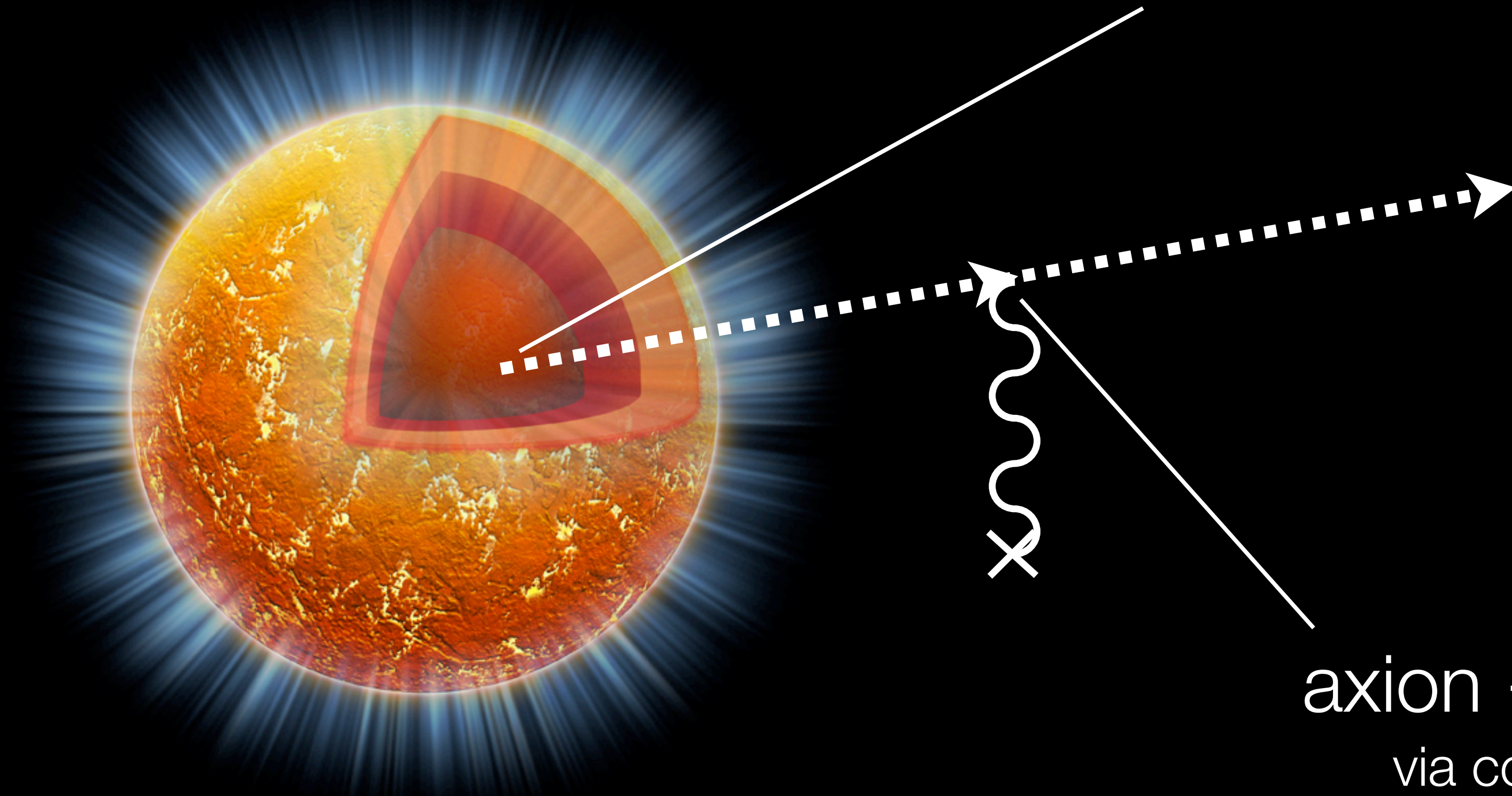
axion production  
via bremsstrahlung and  
Cooper pair formation / breaking





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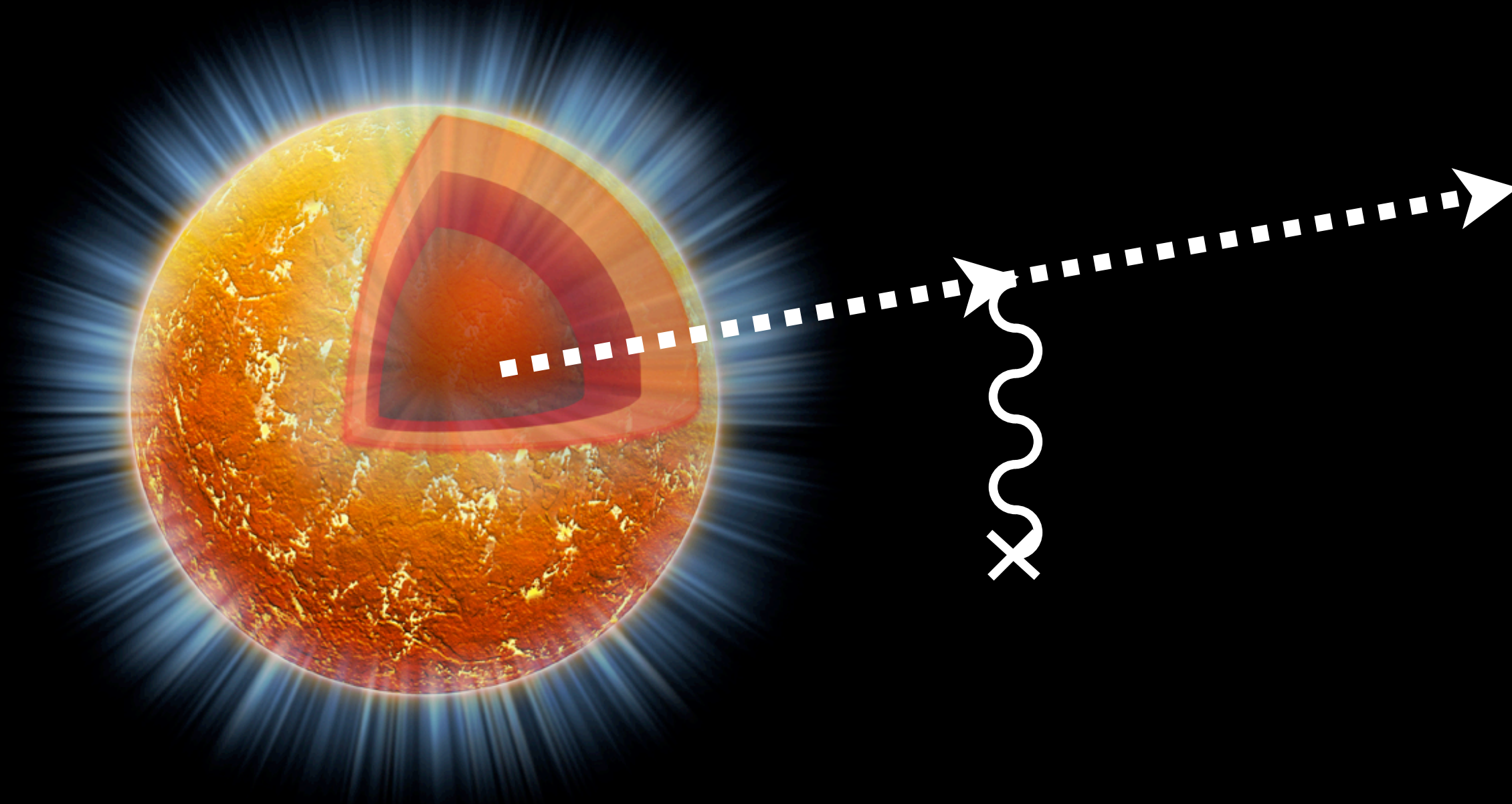
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axion  $\rightarrow$  X-ray conversion  
via coupling to magnetic field



# Axions in Neutron Stars



## Signatures

- anomalous cooling

Raffelt [hep-ph/0611350](#)

Carenza Fore Giannotti Mirizzi Reddy [2010.02943](#)

Buschmann Dessert Foster Long Safdi [2111.09892](#)

Leinson [2105.14745](#)

- hard X-ray emission

Buschmann Co Dessert Safdi [1910.04164](#)

- exciting targets:

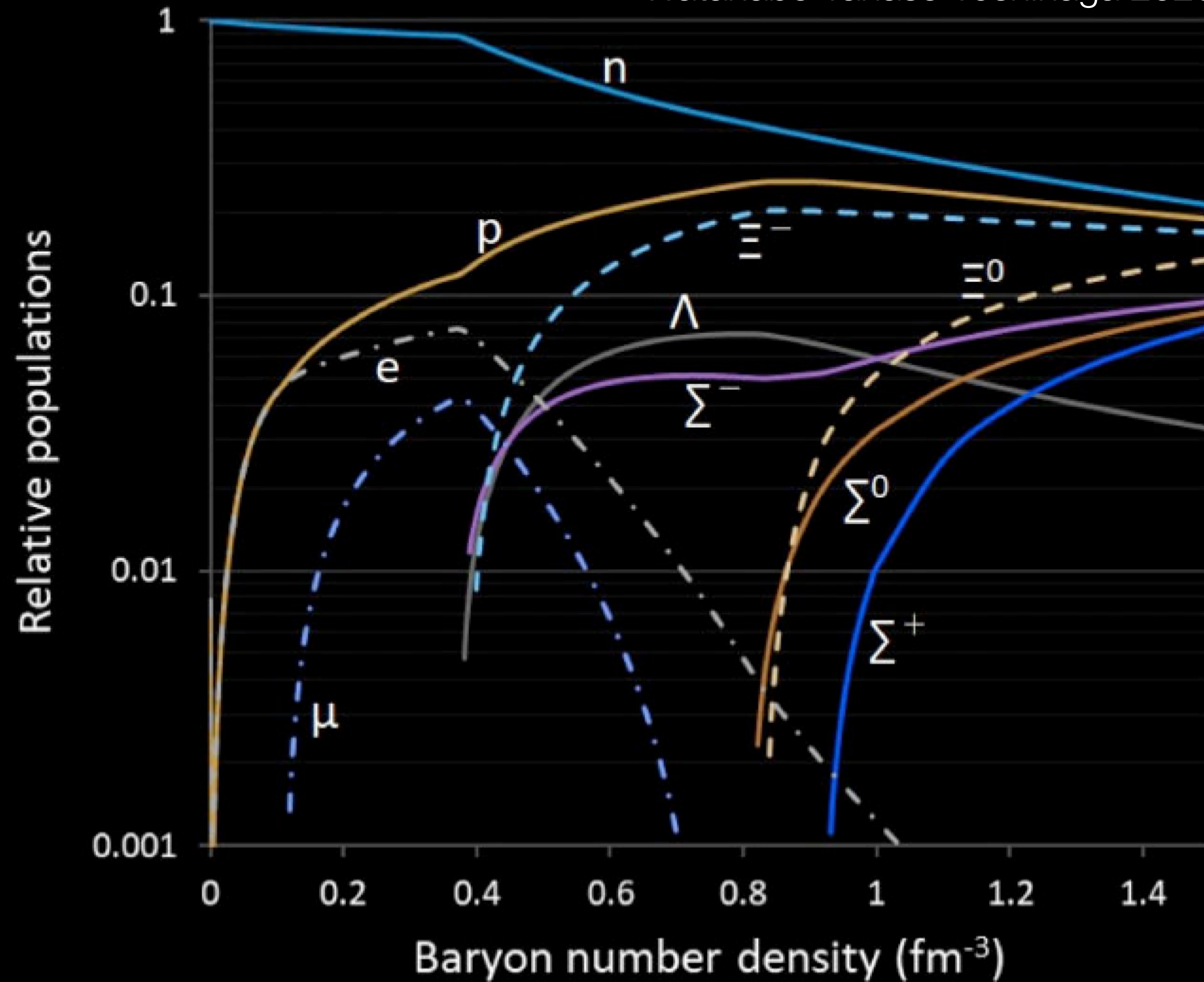
## THE MAGNIFICENT SEVEN

seven nearby, isolated, cold neutron stars with anomalous hard X-ray emission



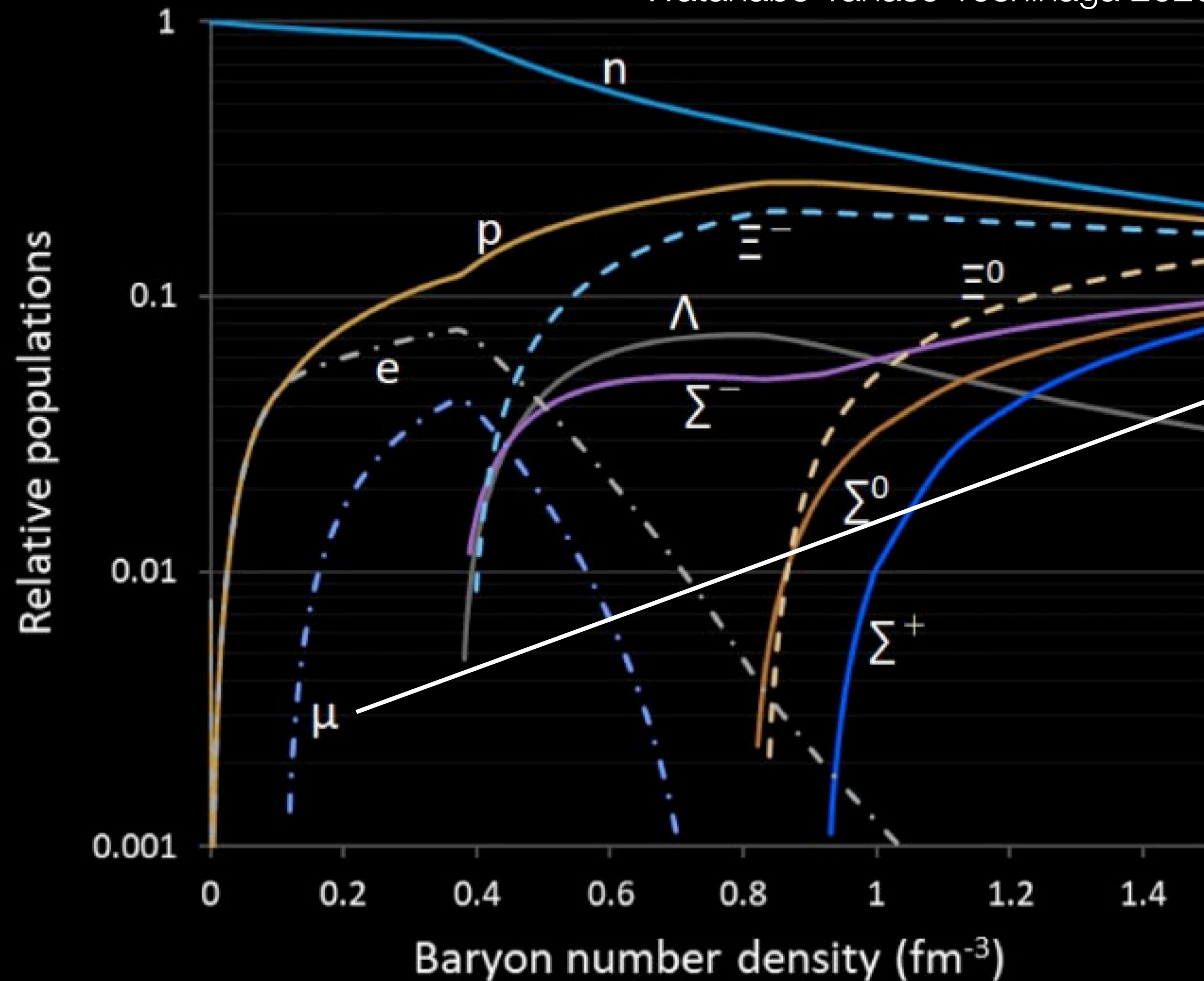
# Muons in Neutron Stars

Watanabe Yanase Yoshinaga 2020



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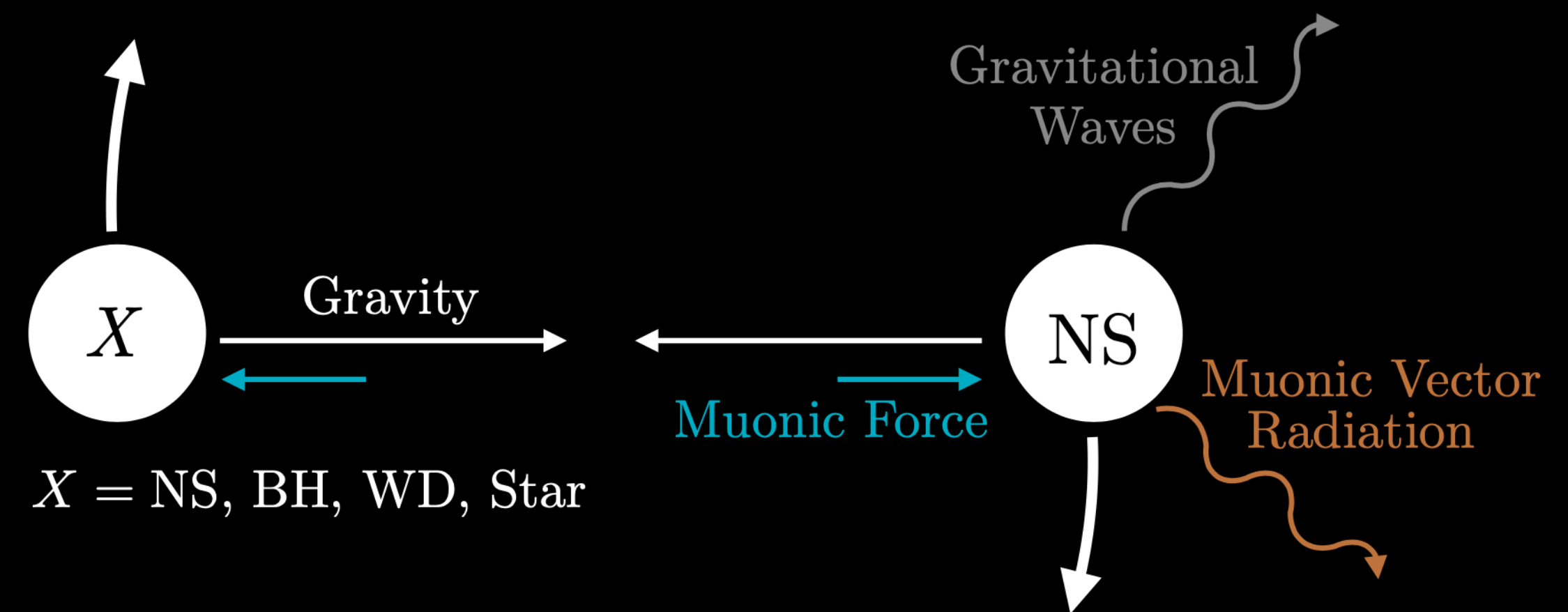
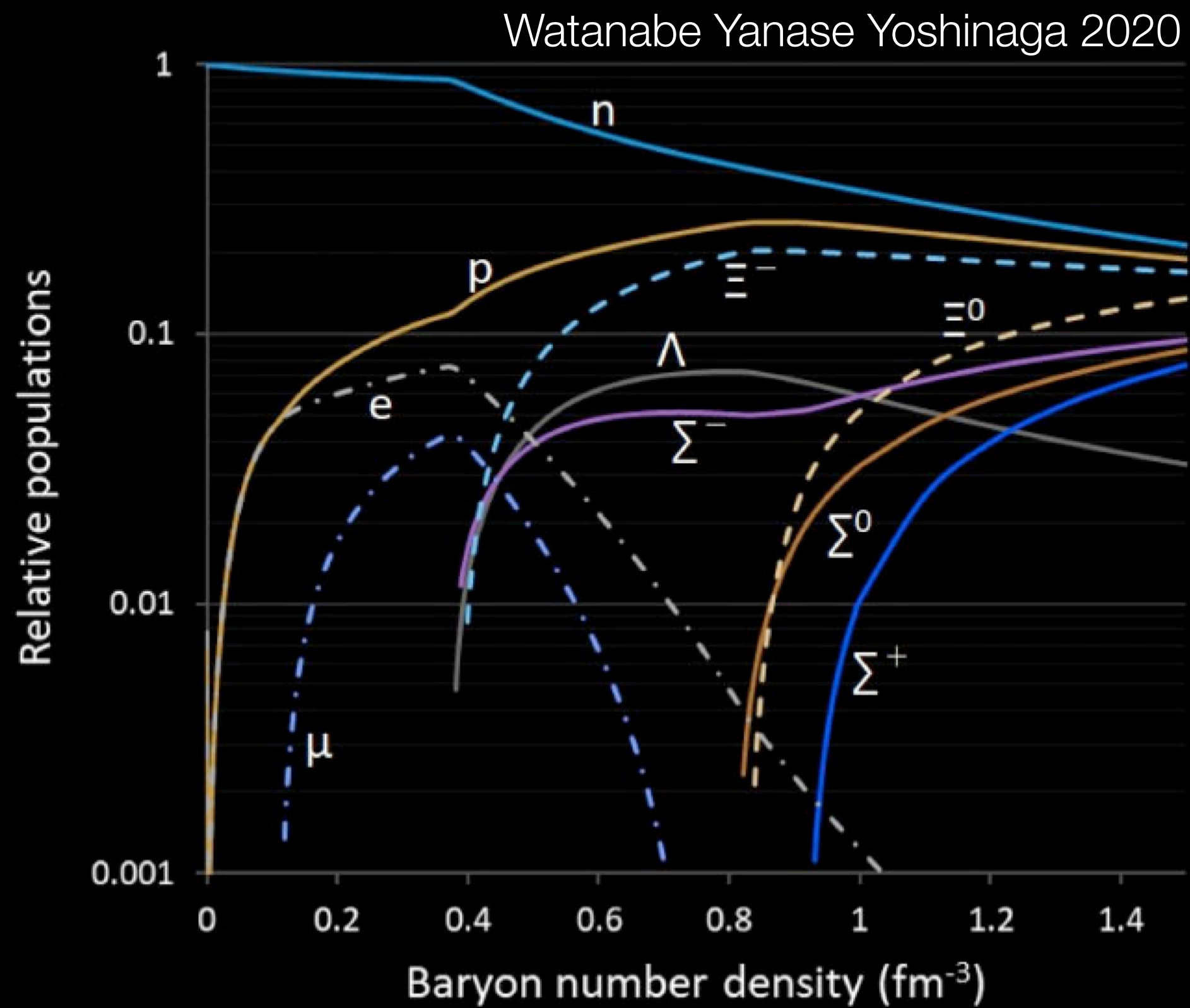


neutron stars harbor abundant quantities of muons



# Muons in Neutron Stars

can be exploited to search for  
**new muonic force**

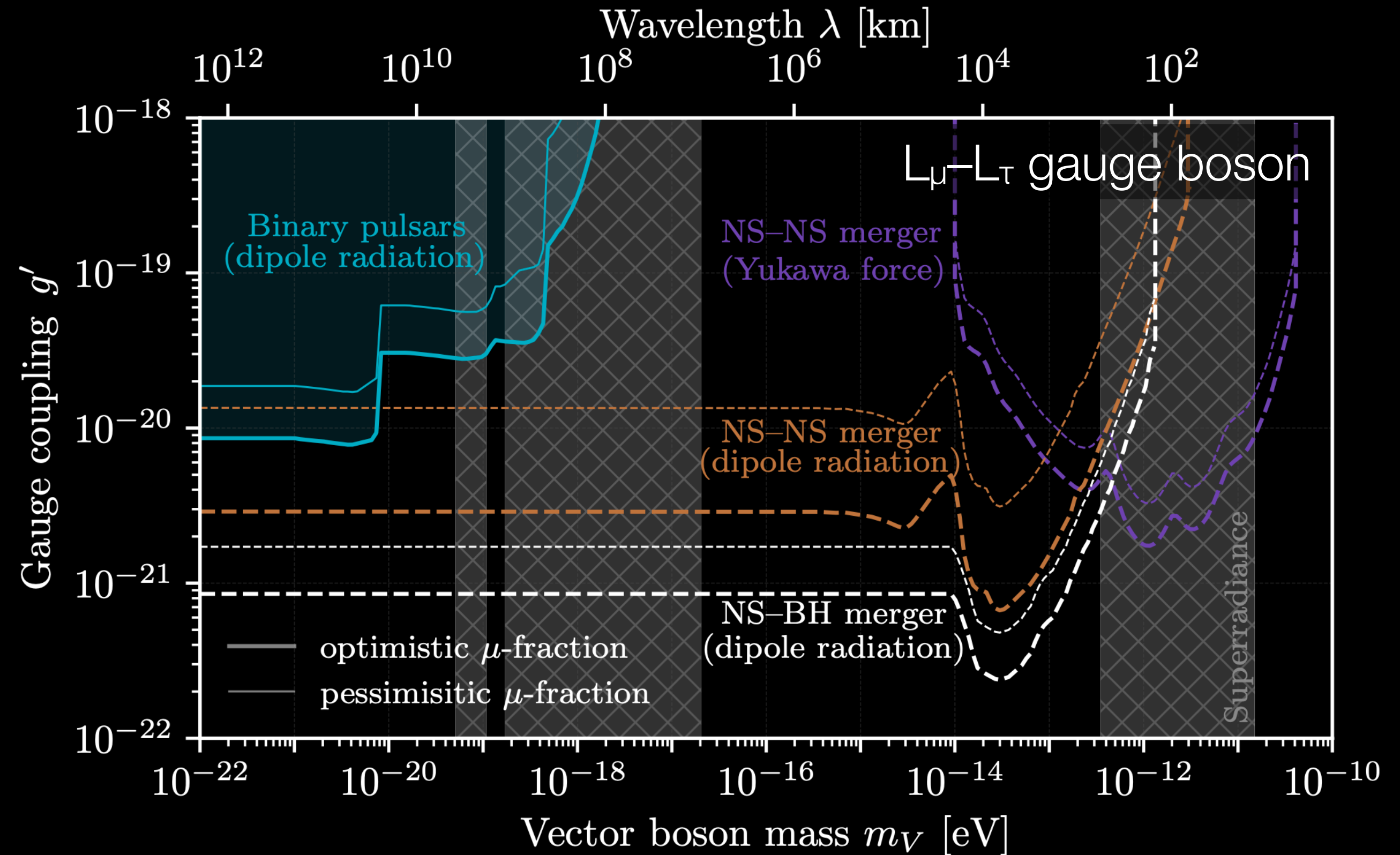
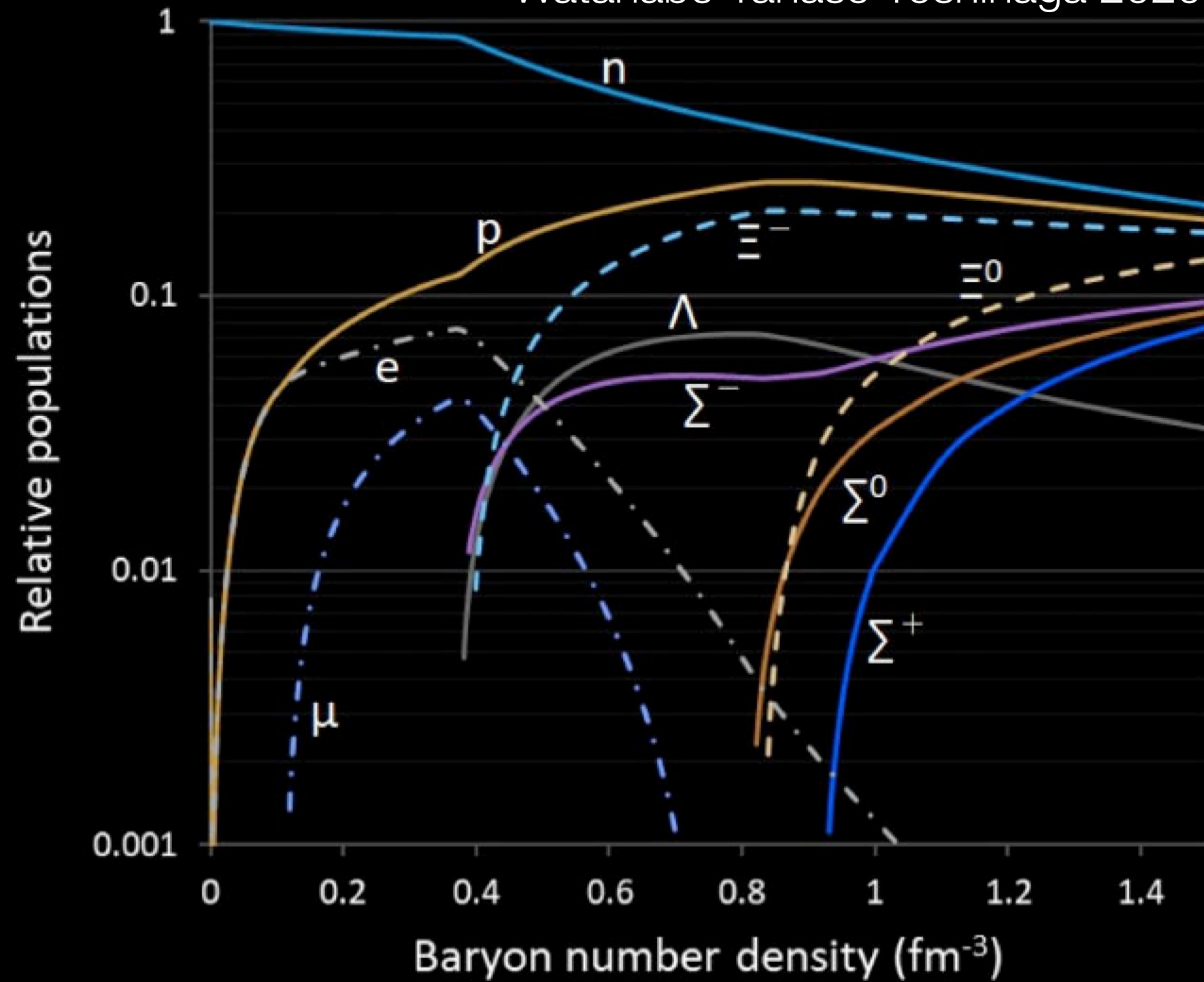


Dror Laha Opferkuch  
1909.12845

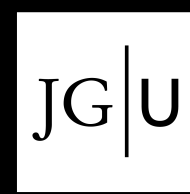
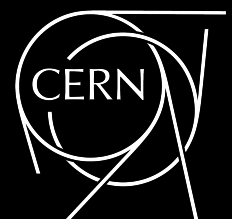
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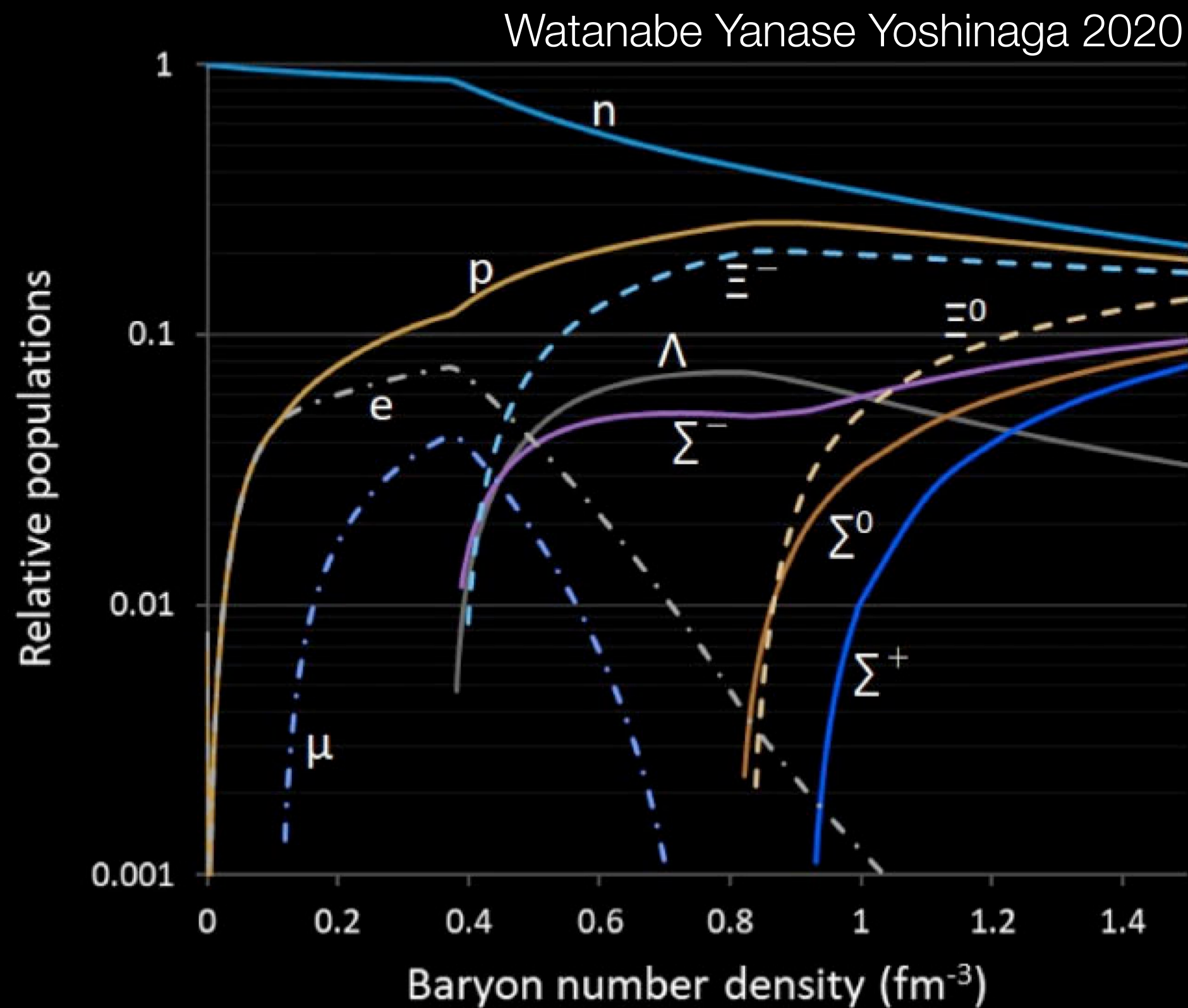


Dror Laha Opferkuch  
 1909.12845





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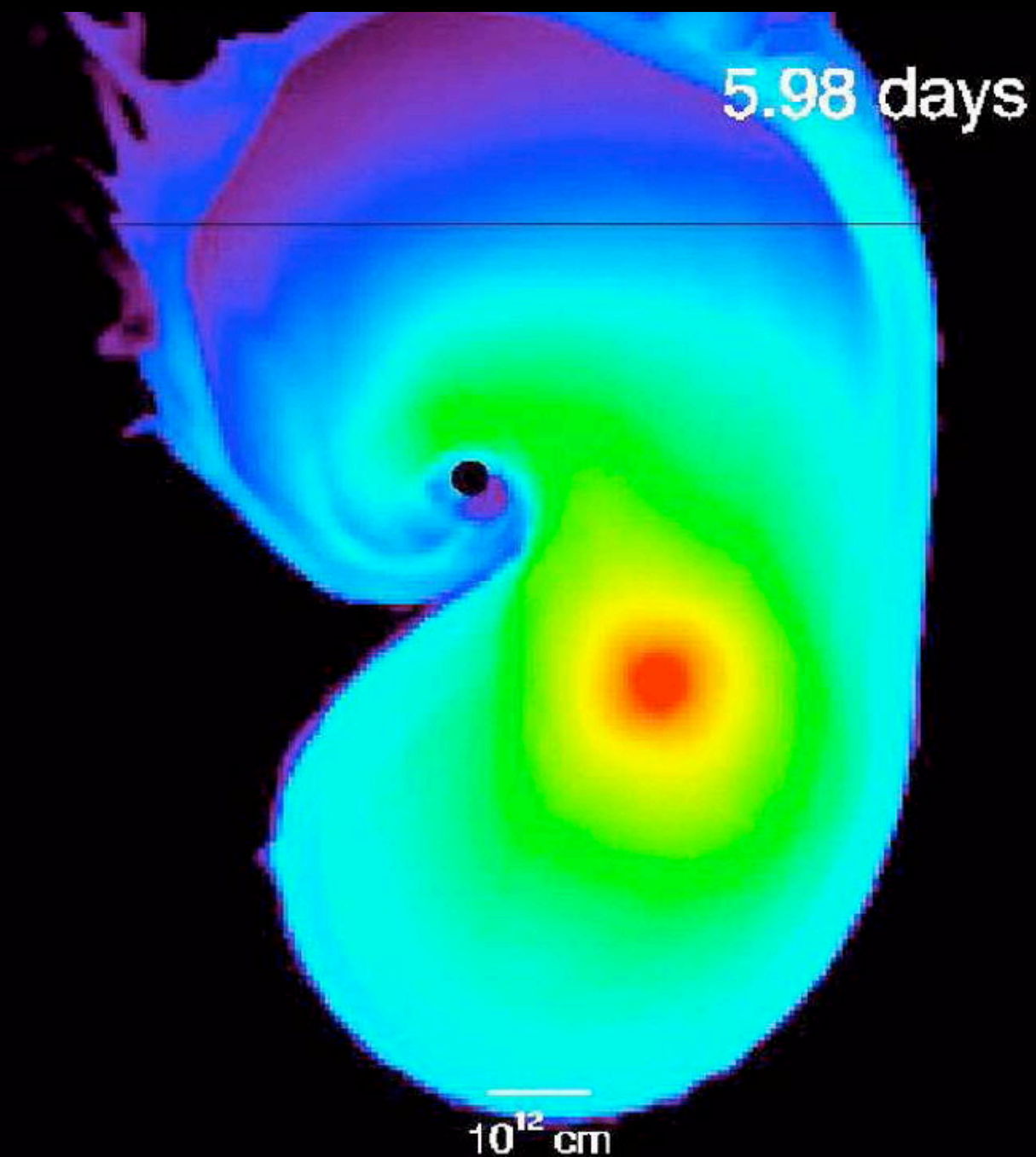


can lead to new **neutrino flux**

- macroscopic changes to the star (rotational velocity, magnetic field)
- ... lead to change in core density
- ... which leads to modified equilibrium muon abundance
- e.g.: tidal deformation prior to merger
- at  $t \gtrsim 10^4$  yrs, weak interactions too slow to maintain equilibrium
- muons diffuse outward and decay  
    ▮▮▮▮ → **neutrinos!**
- flux probably too low to be observable

JK Operkuch *in preparation*

# Common-Envelope Evolution



Taam Ricker 2010

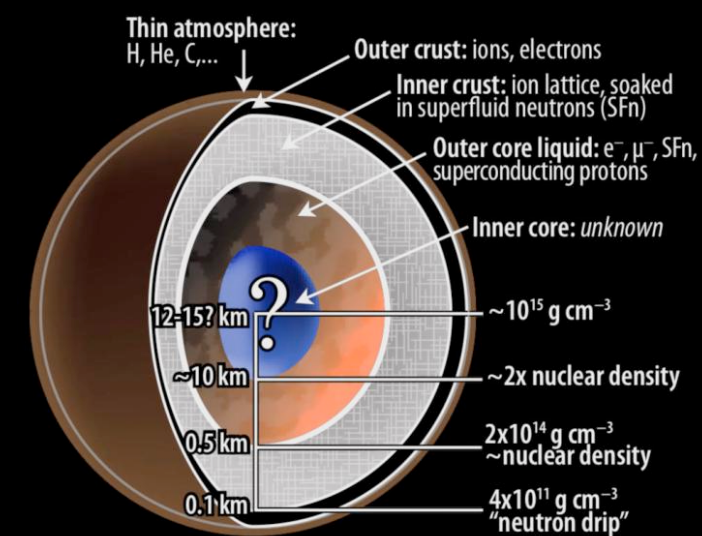
- neutron star may enter the outer layers of a companion in a binary system
- rate  $\approx$  core collapse SN rate
- gigantic accretion rates (up to  $0.1 M_{\odot}/\text{yr}$ ) sustained for months
- accreted material incorporated via weak interactions (de-protonization)  
⇒ neutrinos!

Beacom Esteban JK *in preparation*



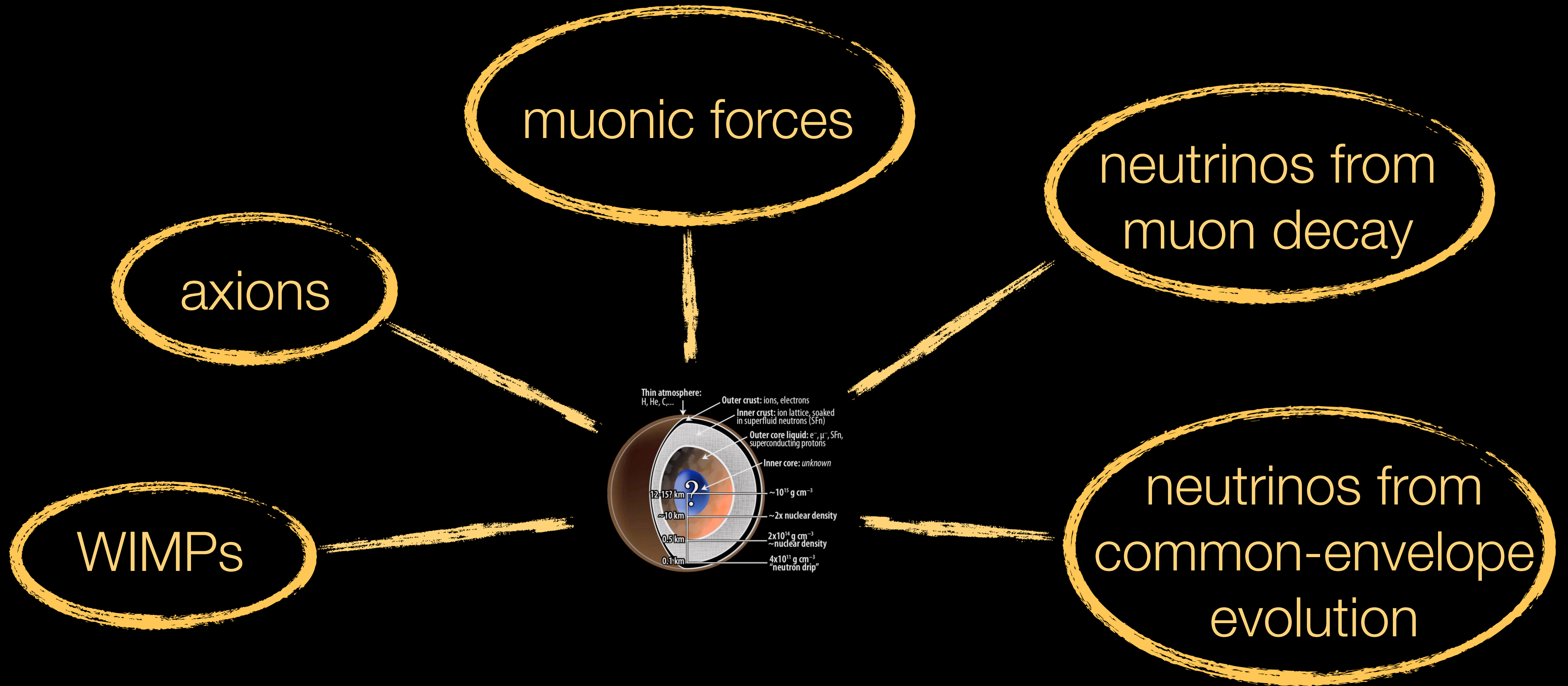


# Summary





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**Thank You!**



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