## **Neutron star as target of Dark Matter**

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# **Neutron Star as target of Dark Matter (1/2)**



 $\frac{dN}{dt} = \sqrt{\frac{6}{\pi}} \cdot \pi b_{\text{max}}^2 \cdot v_{\text{loc}} \cdot \frac{\rho_{\text{loc}}}{m_{DM}} \simeq 10^{22} \text{ s}^{-1}$ 

[C. Kovaris (2008)]

Thermalization

#### Surface Temperature $(T_{c})$



## $E_{\rm recoil} \simeq 1 \,\,{\rm GeV}$



 $v_{\rm loc} \simeq 230 \text{ km/s}$  $\rho_{\rm loc} \simeq 0.3 \text{ GeV/cm}^3$ 

## **Neutron Star as target of Dark Matter (2/2)**



[C. Kovaris (2008)] [M. Baryakhtar et al. (2017)] ···

## Neutron Star obs. vs Direct detection

#### **Sensitivity as target**

$$\sigma_{\rm th} \equiv \frac{\pi R_{\rm NS}^2 m_n}{M_{\rm NS}} \simeq 2.5 \times 10^{-45} \,\rm cm^2$$
$$\Delta M_{\rm NS} \simeq m_n \left( 1 - \frac{2GM_{\rm NS}}{R_{\rm NS}} \right)^{-\frac{1}{2}} \simeq 300 \,\,\rm MeV$$

## **Inelastic DM scattering**

[MF. K. Hamaguchi, N. Nagata,

 $\chi^0$ 

N

 $\Delta M = \chi^{0'}$ 

N

- Large energy injection due to gravitational acceleration
- DM may be excited
- eg. Electroweak multiplet DM

$$\Delta M_{\rm EW} \simeq \alpha_2 m_W \simeq \mathcal{O}(100) \,\,{\rm MeV}$$



# **Possible "Contamination"?**

## **Old but Still Warm**

- We "assume" there is no late time heating source
- Recently, old but warm stars has been observed w/ $T_{\rm s} \simeq 10^4 - 10^6 \, {\rm K}$
- Serious contamination for DM search happens if neutron stars are dominated by the following heating:

□ Internal heating

□ Universal effects

□ Quantitative relevance against DM heating

e.g. Vortex Creep Heating

[Alpar, Pines, Anderson, Shaham (1984)] [Shibazaki, Lamb (1989)] [Gonzalez, Reisenegger (2010)]

 $T\infty$ 



#### Can we really probe DM heating effects? Stay tuned for our future collaboration!

[MF, K. Hamaguchi, N. Natsumi, M. E. Rarmirez-Quezada (on-going)] 103



# Summary

#### We only know few facts about DM (even if we focus on particle dark matter candidates)

In particle physics approach, our final goal is "Identification of DM" (e.g. Determining DM mass, spin, interactions, ...)

- If DM has interaction with the SM particles, we may probe DM through (1) Collider (2) Indirect detection (3) Direct detection
- New direction to probe DM?
  - $\rightarrow$  Neutron star as target of DM (gravitational capture & semi-relativistic recoil)
- What is good observable? Neutron star temperature observation? → We need to examine internal heating of neutron star (e.g. vortex creep)

Experimental/Observational/Astrophysical inputs are indispensable to study/probe DM

Let's work together & explore particle aspect of dark matter w/ your astro-knowledge!

