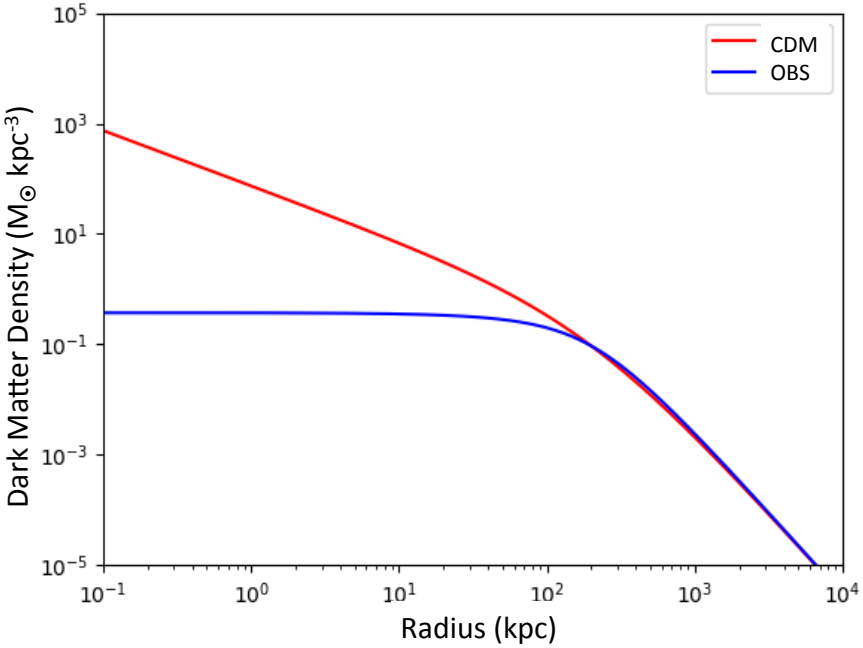
Self Interacting Dark Matter (SIDM)

Lan Quỳnh Nguyễn, University of Notre Dame, lnguyen3@nd.edu

Why SIDM?

Aghanim+ Planck Collaboration, Planck 2018

- $\Omega_{DM}h^2 = 0.120 \pm 0.001$
- Small scale structure problems
  - Missing satelline
  - Core cusp problem
  - Too big too fail
- => SIDM (Spergel+ 2000)



What is SIDM?

The cold DM model is not able to explain observations on scales smaller than a few Mpc
The key properties of the SIDM dark matter particles

- have a large scattering cross-section
- negligible annihilation or dissipation
- do not interact with ordinary particles in the standard model

- DM scater elastically with each other at astrophysically interesting rates
- $\Gamma = n\sigma v = \rho \frac{\sigma}{m} v$
- $\frac{\sigma}{m} \sim 1 cm^2 g^{-1}$

Model SIDM

with RH neutrinos provides two Higgs bosons: one is scalar or CP-even and another is pseudoscalar or CP odd particle having properties of candidates for dark matter (Lan+ 2006)

- Coupling of the interaction of DM to the standard Higgs boson

$$L(\sigma,\zeta_\eta) = \left[\frac{\sigma(x)}{\sqrt{\lambda_5^2v^2+\lambda_6^2u^2}}\left(\lambda_1\lambda_5v^2+\frac{\lambda_4\lambda_6}{2}u^2\right)+\frac{H_1(x)\sigma(x)}{(\lambda_5^2v^2+\lambda_6^2u^2)}\left(\lambda_1-\frac{\lambda_4}{2}\right)\lambda_5\lambda_6uv\right.$$
$$\left.+\ \frac{\sigma^2(x)}{2(\lambda_5^2v^2+\lambda_6^2u^2)}\left(\lambda_5^2v^2+\frac{\lambda_6^2}{2}u^2\right)\right]\left(\xi_\eta'^2+\zeta_\eta'^2\right).$$

- The cross section for $hh->hh$ (h stands for ζ_η' and ξ_η') with quartic interaction is $\sigma=\frac{\lambda_1}{4\pi m_h^2}$

.

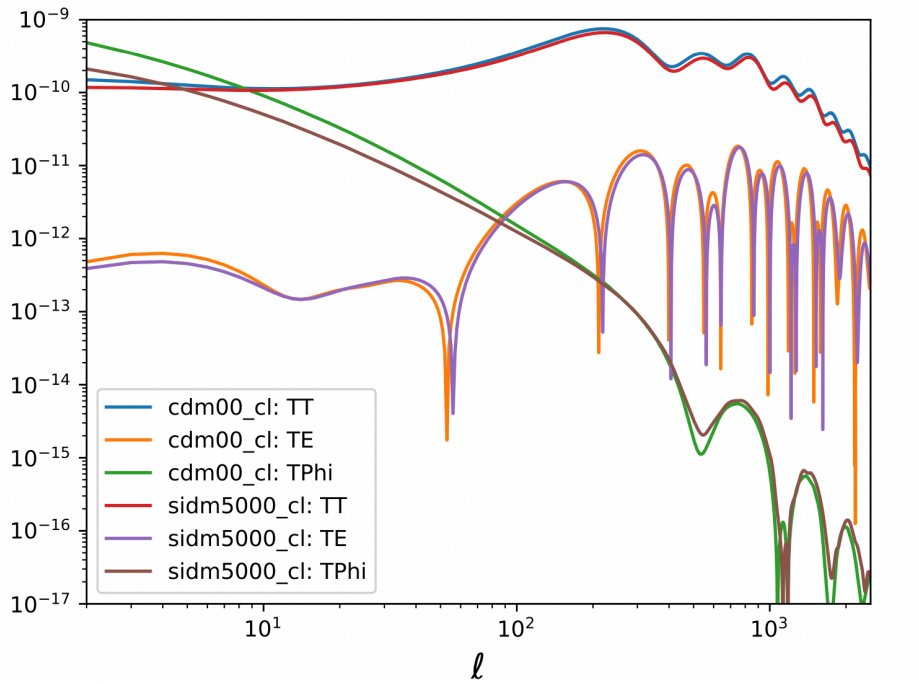
- DM elastic cross section to its mass is:
- $$2.05 \times 10^3 \ \mathrm{GeV}^{-3} \leq \frac{\sigma}{m_h} \leq 2.57 \times 10^4 \ \mathrm{GeV}^{-3}$$
- SIDM mass. $4.7MeV \leqslant m_h \leqslant 23MeV$
- Cosmic density of the h scalar given by $$\Omega_h = 2g(T_\gamma)T_\gamma^3 \frac{m_h \beta}{\rho_c g(T)}$$
-

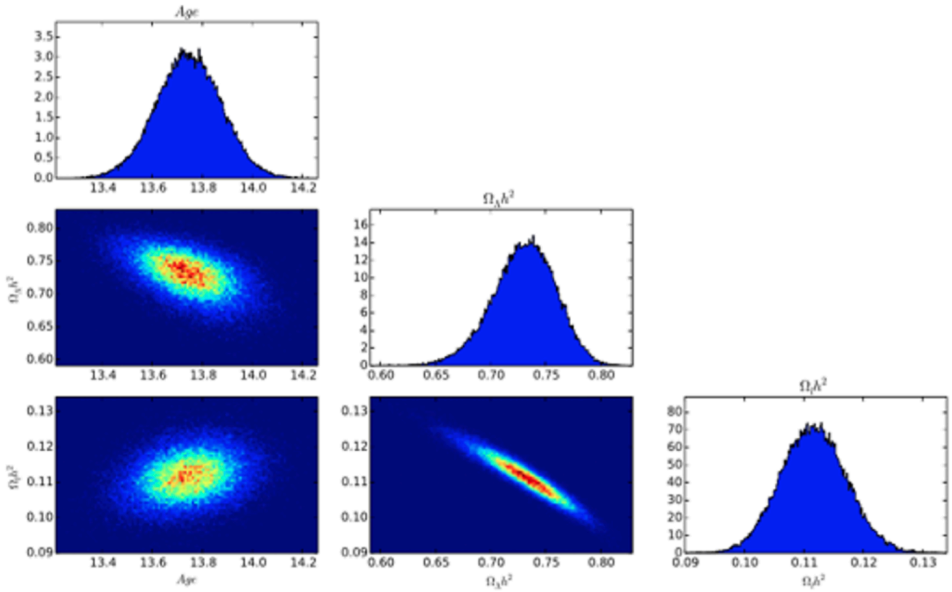
Constraint of the SIDM

1. SIDM and small scale structure problems
2. SIDM and tidal deformability NS
3. SIDM and GW gravitational lensing

SIDM and Small Scale Structure

- SIDM and core cusp problem: constrain with CMB (Lan+ 2021)





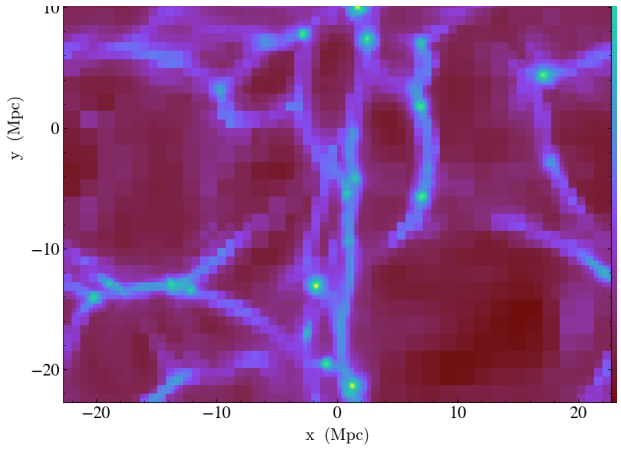
SIDM and Small Scale Structure

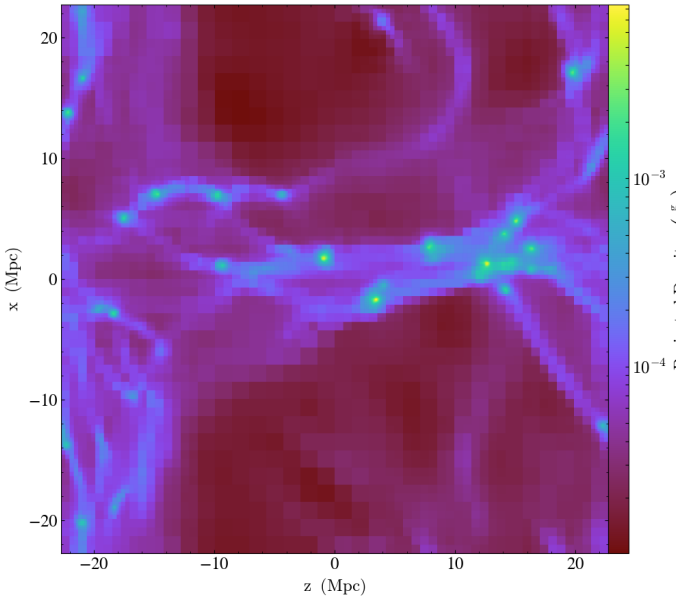
- SIDM and core cusp problem: constrain with galaxy simulation (Lan+ 2021)

For simulations, we set the initial conditions (Komatsu+ 2011).

$\Omega\Lambda = 0.734, \Omega_m = 0.266, \Omega_b = 0.0449, n_s = 0.963, h = 0.71, \sigma 8 = 0.801$

Name	Volume $(h^{-1}Mpc)$	N_p	Cross section $\frac{\sigma}{m}(cm^2g^{-1})$
CDM	50	512^3	0
SIDM-3.5	50	512^3	3.7
SIDM-5.5	50	512^3	5.2





SIDM and Gravitational Wave

- Effect of dark matter on Binary Neutron Merges (Nelson+ 2019)

- SIDM and tidal deformability NS (Lan+ 2022 prep.)

SIDM Experiment

- beryllium-8 nuclei for a new boson at the 10 MeV-scale that can be tested by nuclear and atomic spectroscopy experiments (Battaglieri + 2017)

THANK YOU!