The impact of dark matter on compact stars

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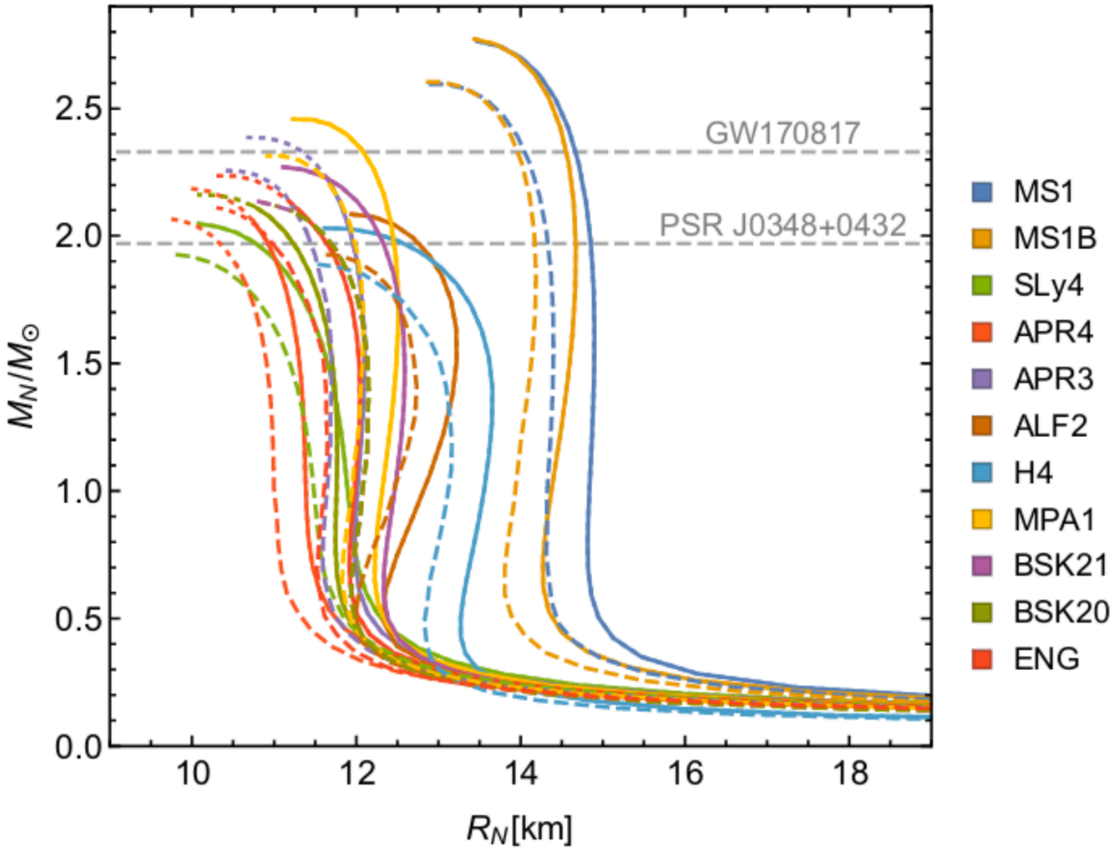
10TH IDPASC SCHOOL

Effects of DM on NSs and their merger



Visible decrease in both neutron stars' (NS) masses and radii due to dark matter (DM) content, using different Equations of State (EoSs).

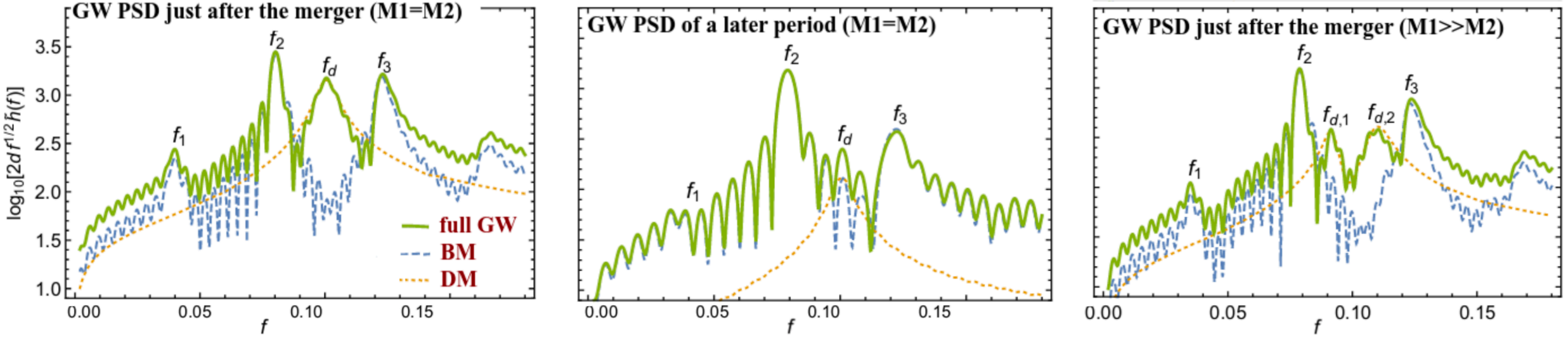
The DM fraction is set at 5%. While solid lines represent pure BM (baryonic matter), dashed ones the DM+BM EoS.

M. Deliyergiyev et al., PRD 99, 063015 (2019)
A. Del Popolo et al., Phys. D. Univ. 28, 100484 (2020) J.
Ellis et al., PRD 97, 123007 (2018)

Effects of DM on NSs and their merger

Symmetric system (stars with equal masses)

Asymmetric system (stars with different masses)



Gravitational waves frequency peaks (f_i, f_D) in symmetric and strongly asymmetric systems.

J. Ellis et al., PLB, 781, 607 (2018)
M. Bezares et al., PRD, 100, 044049 (2019)

Constraints on the DM-admixed NSs

Astrophysical constraints

- Existence of the $2M_\odot$ NSs: PSR J0348-0432: $M = 2.01^{+0.04}_{-0.04}\ M_\odot$ and PSR J0740+6620: $M = 2.14^{+0.20}_{-0.18}\ M_\odot$ Antoniadis et al.'(2013), Cromartie et al (2019) ;
- Astrophysical observations;
- Tidal deformability constraints from the NS-NS mergers (GW170817, GW190425).

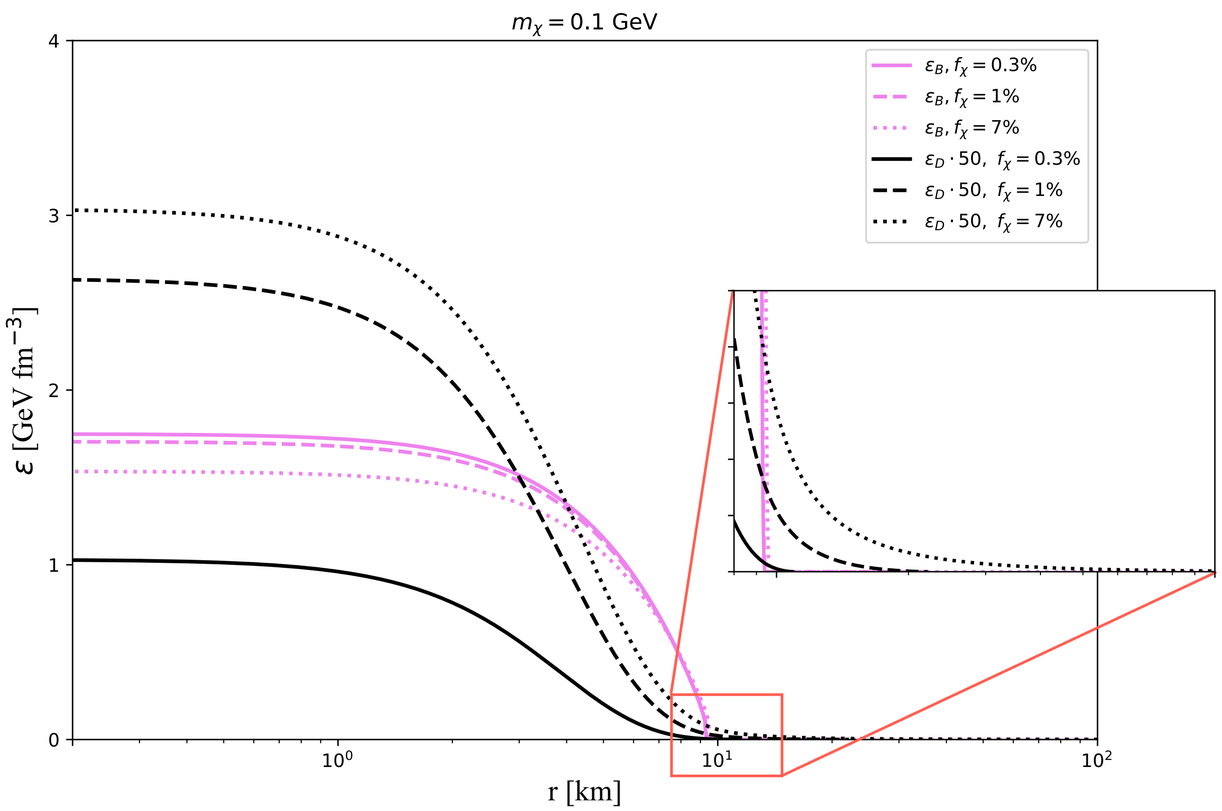
Baryonic matter EoS - Induced Surface Tension (IST) EoS V. Sagun *et al* 2019 *ApJ* **871** 157

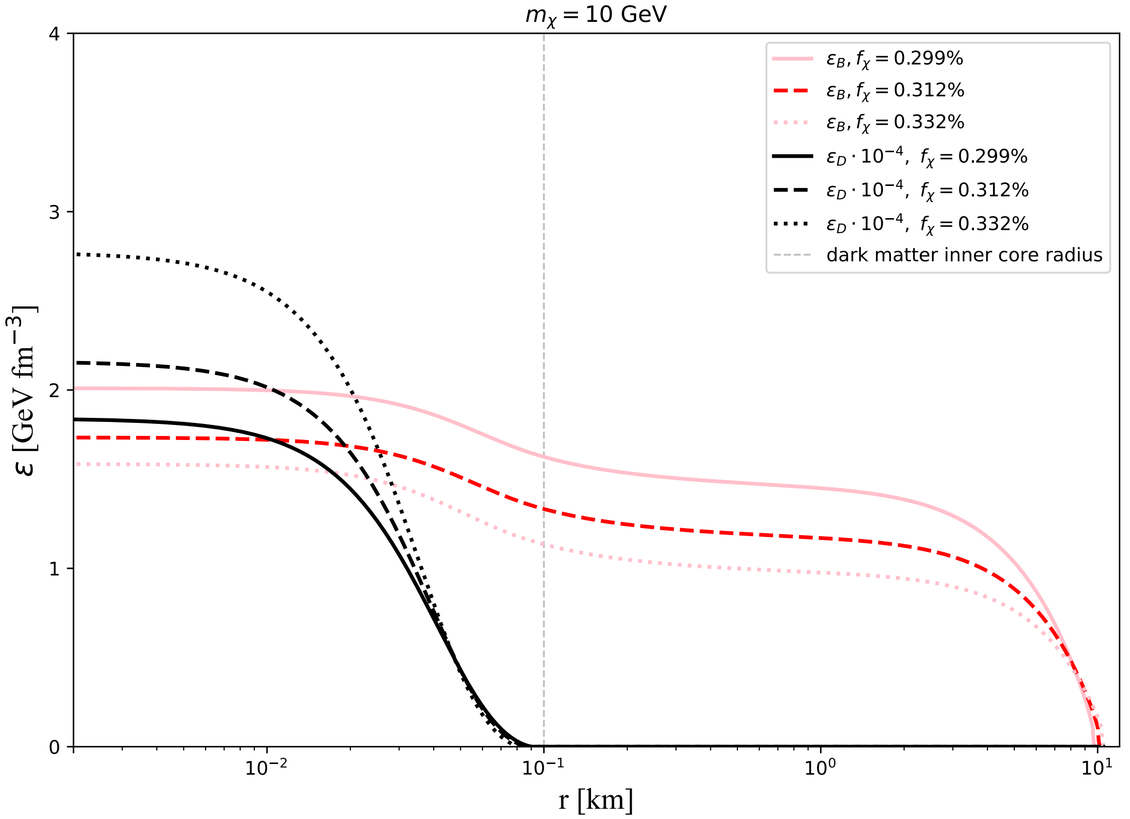
- Nuclear matter ground state properties;
- Proton flow data;
- Heavy-ion collisions data.

Dark Matter EoS

Non-interacting Fermi gas of relativistic particles with spin $\frac{1}{2}$, coupled to BM through gravity.

Haloes or cores?





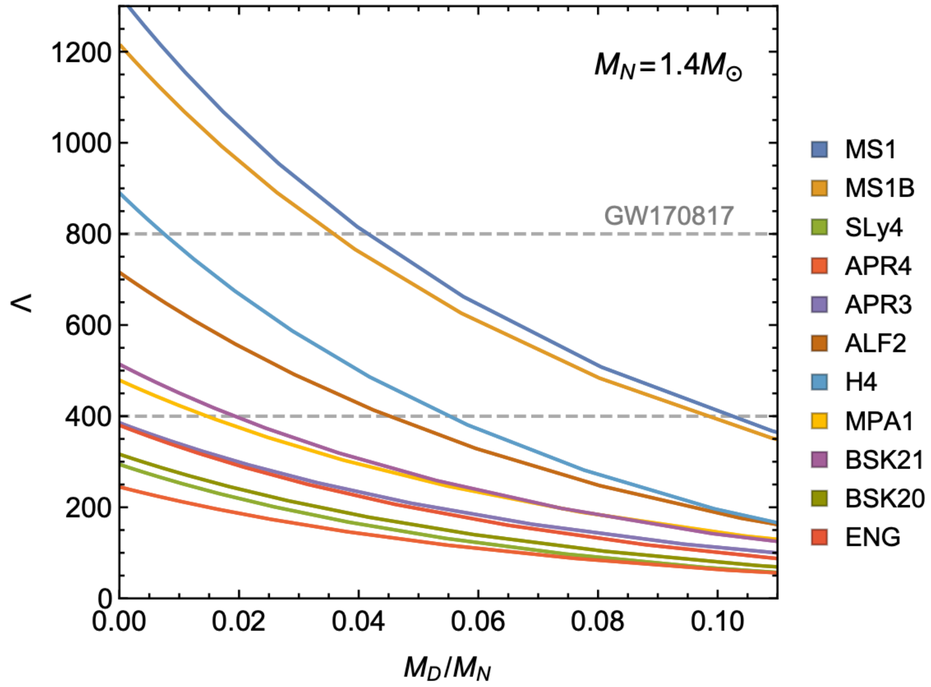
Energy density profiles showing different DM configurations for different DM particle masses.

Ivanytskyi et al. Phys. Rev. D 102, 063028 (2020)

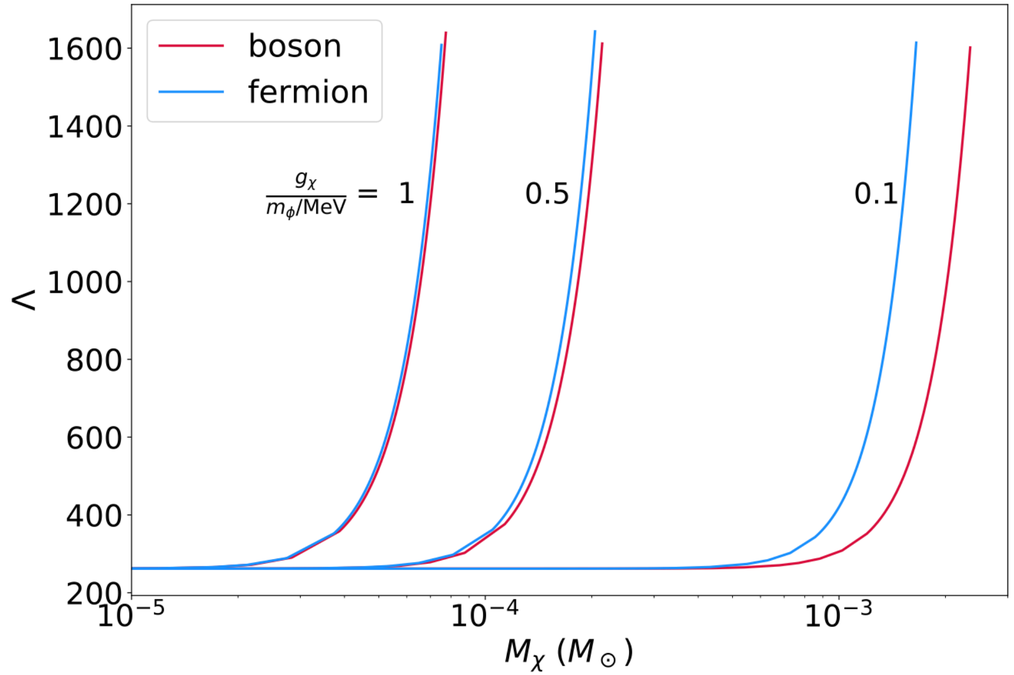
In the plots, f_X stands for the DM fraction.

Tidal deformability parameter

DM core



DM halo



Tidal deformability parameter Λ changes with core formation (on the left) and halo formation (on the right).

J. Ellis et al., PLB, 781, 607 (2018)
A. Nelson et al., JCAP 7, 12 (2019)

$\Lambda = \frac{2}{3} k_2 \left(\frac{R}{M}\right)^5$ where k_2 is the Love's number, M and R the NS's mass and radius.

Future PhD tasks

- Calculate properties of DM-admixed NSs with self-interacting fermionic and bosonic DM;
- Perform numerical simulations of coalescence of binary DM-admixed NSs;
- Using astrophysical and gravitational waves (GW) observations to constrain DM properties.

Radio Telescopes

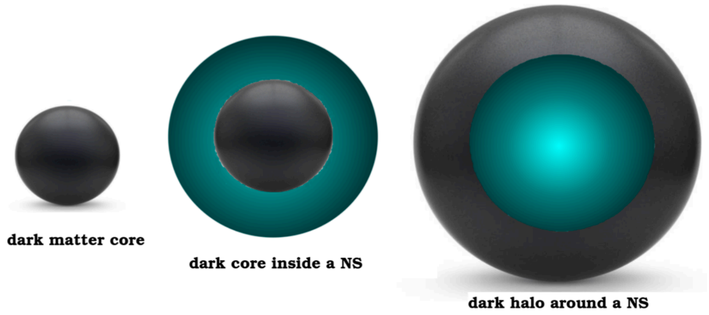
- the Karoo Array Telescope (MeerKAT);
- the Square Kilometer Array (SKA);
- the Next Generation Very Large Array (ngVLA).

X-Ray Telescopes

- the Neutron Star Interior Composition Explorer Mission (NICER);
- the Advanced Telescope for High Energy Astrophysics (ATHENA);
- the enhanced X-ray Timing and Polarimetry mission (eXTP);
- the Spectroscopic Time-Resolving Observatory for Broadband Energy X-rays (STROBE-X);

GW interferometers

- Laser Interferometer Gravitational-Wave Observatory (LIGO);
- VIRGO interferometer;
- KAmioka GRAvitational Wave Detector (KAGRA).



Thanks for your attention!