Correlating the neutron skin to the neutron star crust-core transition

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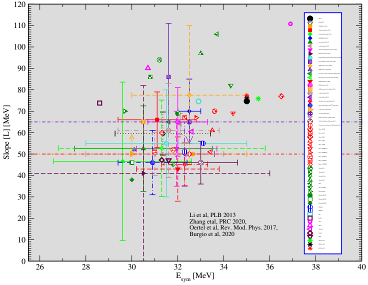
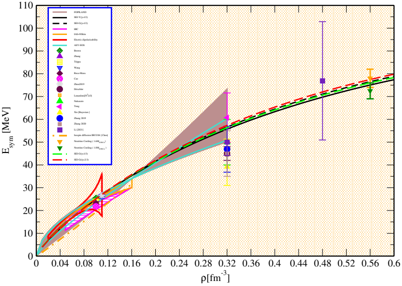
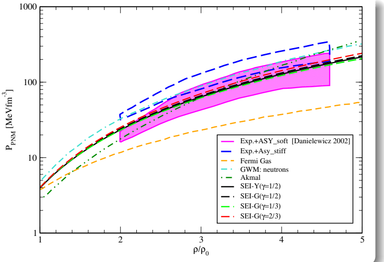
Nuclear Symmetry energy





Experiments/Theoretical interactions	$E_{sym}(2\rho_0)$[MeV]
SEI-Y($\gamma = 1/2$)	55.38
chiral effective field theory (χEFT) [Drischler2020]	45±3
Quantum Monte Carlo calculations using chiral EFT(N^2LO) [Lonardoni2020]	46±4
Neutron Star Observables Since GW170817 [Li21]	51±13
Cooling process of a protoneutron star (PNS) [Nakazato2019]	40-60
Gravitational waves from GW170817 [Tong2020]	60.7±10.9
Bayesian Inference from Radii of Canonical Neutron Stars [Xie2019]	$39.2^{+12.1}_{-8.2}$
Skyrme energy density functional [Zhang2020]	35-55
Electromagnetic and gravitational measurements of Neutron stars [Zhou2019]	$[39.4^{-6.4}_{+7.5}, 54.5^{-3.2}_{+3.1}]$
Microscopic calculations with various energy density functionals [Chen2015]	40.2±12.8
Extended Skyrme-Hartree-Fock (eSHF) model and from PREX-II [Gang Yue2022]	62.8±15.9
Bayesian Inference from Future Radius Measurements of Massive Neutron Stars [J Xie2020]	47^{+23}_{-22}
Experiments/Theoretical interactions	$E_{sym}(3\rho_0)$[MeV]
SEI-Y($\gamma = 1/2$)	69.38
From Neutron Star Observables Since GW170817 [Li21]	$76.91^{+25.96}_{-25.96}$



THE NEUTRON STAR CORE-CRUST TRANSITION

Dynamical method

$$V_{dyn}(\rho,k) = \left(\frac{\partial\mu_p}{\partial\rho_p} + D_{pp}(\rho,k) + \frac{4\pi e^2}{k^2}\right) - \frac{[\partial\mu_n/\partial\rho_p + D_{np}(\rho,k)]^2}{\partial\mu_n/\partial\rho_n + D_{nn}(\rho,k)} - \frac{(4\pi e^2)^2}{\partial\mu_e/\partial\rho_e + 4\pi e^2/k^2}$$

Thermodynamical Method

$$V_{Therm} = 2\rho\frac{\partial E_b(\rho,y_p)}{\partial\rho^2} + \rho^2\frac{\partial^2 E_b(\rho,y_p)}{\partial\rho^2} - \left(\frac{\partial^2 E_b(\rho,y_p)}{\partial\rho\partial y_p}\rho\right)^2 \Big/ \frac{\partial^2 E_b(\rho,y_p)}{\partial^2 y_p}$$

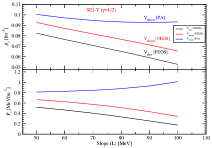
Simple Effective Interaction (SEI)

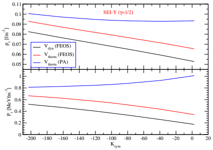
$$V_{eff}(r) = t_0(1+x_0P_\sigma)\delta(r) + \frac{t_3}{6}(1+x_3P_\sigma)\left(\frac{\rho}{1+b\rho}\right)^\gamma\delta(r) + (W + BP_\sigma - HP_\tau - MP_\sigma P_\tau)\mathbf{f(r)}$$

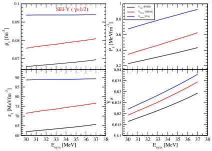
f(r)= $\frac{e^{-r/\alpha}}{r/\alpha}$ (Yukawa), e^{-r^2/α^2} (Gaussian), $e^{-r/\alpha}$ (Exponential).

SEI has 11 parameters: b, t_0, x_0, t_3, x_3, γ, α, W, B, H, M + W_0 $\Rightarrow$ Enters in the description of finite nuclei.

SEI-Y(K=240 MeV)	$\rho_t[fm^{-3}]$	$P_t[MeV fm^{-3}]$	$\varepsilon_t[MeV fm^{-3}]$	Y_{pt}
$V_{dynamical}$	0.0681	0.3710	64.4184	0.02505
$V_{Therm}[FEOS]$	0.0794	0.54572	75.1822	0.0295
$V_{Therm}[PA]$	0.0939	0.85841	89.04812	0.0329
SEI-G($V_{Therm}[FEOS]$)				
K[MeV]	$\rho_t[fm^{-3}]$	$P_t[MeV fm^{-3}]$	$\varepsilon_t[MeV fm^{-3}]$	Y_{pt}
226	0.0788	0.55536	74.6214	0.03001
245	0.08	0.55831	75.7561	0.02968
263	0.082	0.5888	77.6752	0.03068



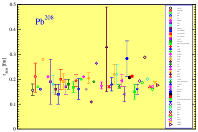


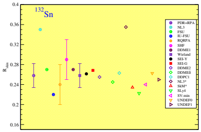


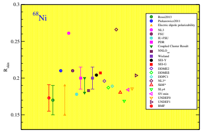
Finite Nuclei: The quasilocal energy functional: $\varepsilon_0[\rho^{QL}] = \int H_0 d^3R$

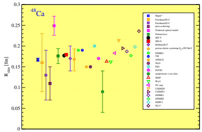
- $H_0 = \frac{\hbar^2}{2m}(\tau_n + \tau_p) + H_d^{Nucl} + H_{exch}^{Nucl} + H^{SO} + H^{Coul}$

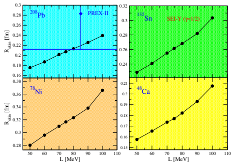
Neutron-skin thickness($R_{skin} = R_n - R_p$)

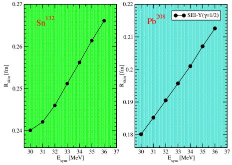












SEI-G	R_{skin}[fm]			
K[MeV]	Ca^{48}	Ni^{78}	Sn^{132}	Pb^{208}
226	0.1782	0.326	0.2684	0.2118
245	0.179	0.3237	0.2666	0.2103
263	0.1791	0.3221	0.2662	0.207

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Thank you for your kind attention