FINITE RANGE THOMAS FERMI MODEL

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Equation of states for hot dense matter

Non relativistic potential model

- $\mathcal{H} = \mathcal{H}_{\mathcal{B}} + \mathcal{H}_{\nabla} + \mathcal{H}_{\mathcal{C}} + \mathcal{H}_{\mathcal{J}}$
- Composed of kinetic energy term, zero range multi-force, s and p wave two body interaction, Coulomb interaction, spin-orbit coupling

Mean Field Model

- $\mathcal{L} = \mathcal{L}(\psi, \mathcal{A}_{\mu}, \rho, \omega, \sigma)$
- Nuclear force is mediated by ρ, ω, and σ mesons
- Needs 17 parameters, difficult to use numerically.

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Myers and Swiatecki(1990)

- $v_{12} = v(r_{12}, p_{12}, \bar{\rho}) = -C\, f(r_{12}/a)$
- $f(r_{12}/a) = \frac{1}{4\pi r_{12} a^2} e^{-r_{12}/a}$

  item $C = \frac{1}{2}(1 \pm \xi) C_\alpha - \frac{1}{2}(1 \pm \zeta) \left[C_\beta\, p_{12}^2 - C_\gamma \frac{1}{p_{12}} + C_\sigma \bar{\rho}^{2/3} \right]$
- Describe cold nuclei, Nuclear fission reaction.

Trucated model

- Extend the cold nuclear matter to hot dense matter
- Neglect the inverse momentum interaction - non analytic, difficult to compute numerically, kinetic energy estimated too small.
- $W = -\frac{1}{h^3} \int d^3 r_1 \int d^3 r_2\, f(r_{12}/a) \sum_t \left[\int C_L f_{t1} f_{t2}\, d^3 p_{t1} d^3 p_{t2} + \int C_U f_{t1} f_{t'2}\, d^3 p_{t1} d^3 p_{t'2} \right]$
- $C_{(L,U)}(p_1, p_2, \bar{\rho}) = \frac{h^3}{4} T_0 \rho_0 \left(\frac{3}{4\pi P_0^3} \right)^2 \left[\alpha_{(L,U)} - \beta_{(L,U)} \left(\frac{p_{12}}{P_0} \right)^2 - \sigma_{(L,U)} \left(\frac{2\bar{\rho}}{\rho_0} \right)^{2/3} \right].$

Determination of the parameter

- Nuclear fitting parameters
  - ▷ B=-16MeV, P=0(at saturation density), Sv=31.68MeV, Sv$'$=17.93MeV, m*=0.724m

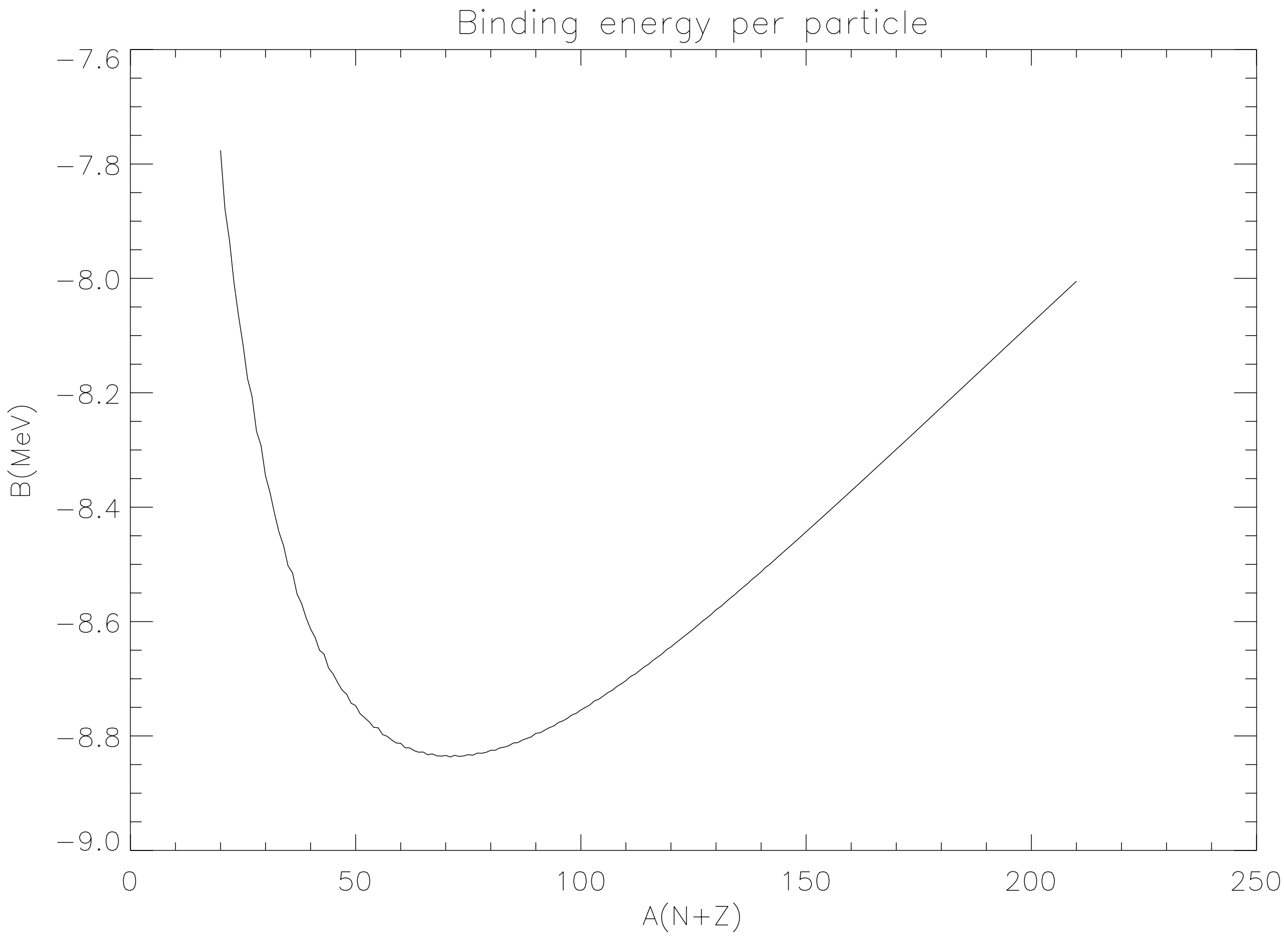
Numerical point of view

- FRTF : integral equation(Euler equation), MFT and Potential model : differential Equation

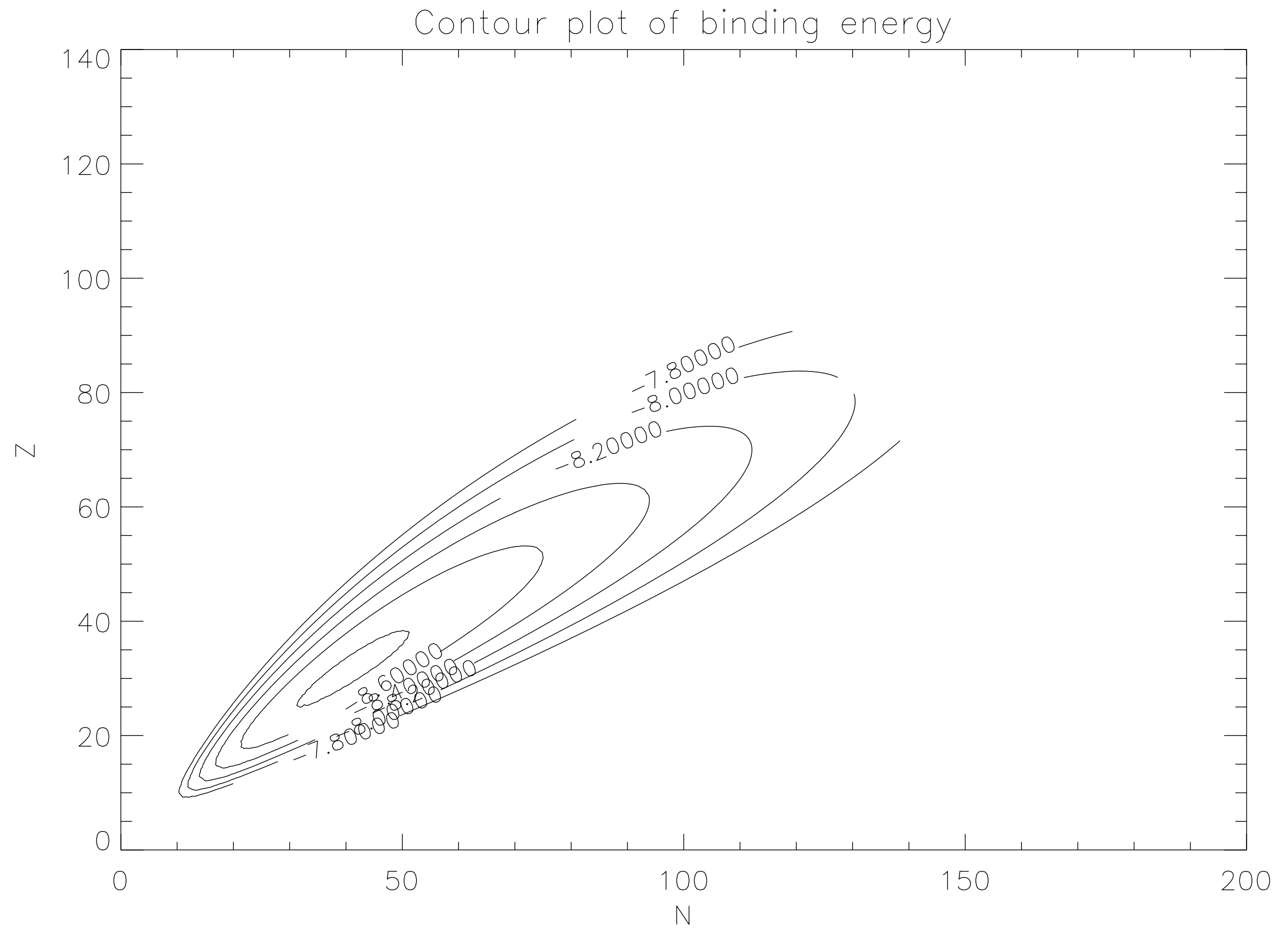
Radius of heavy nuclei

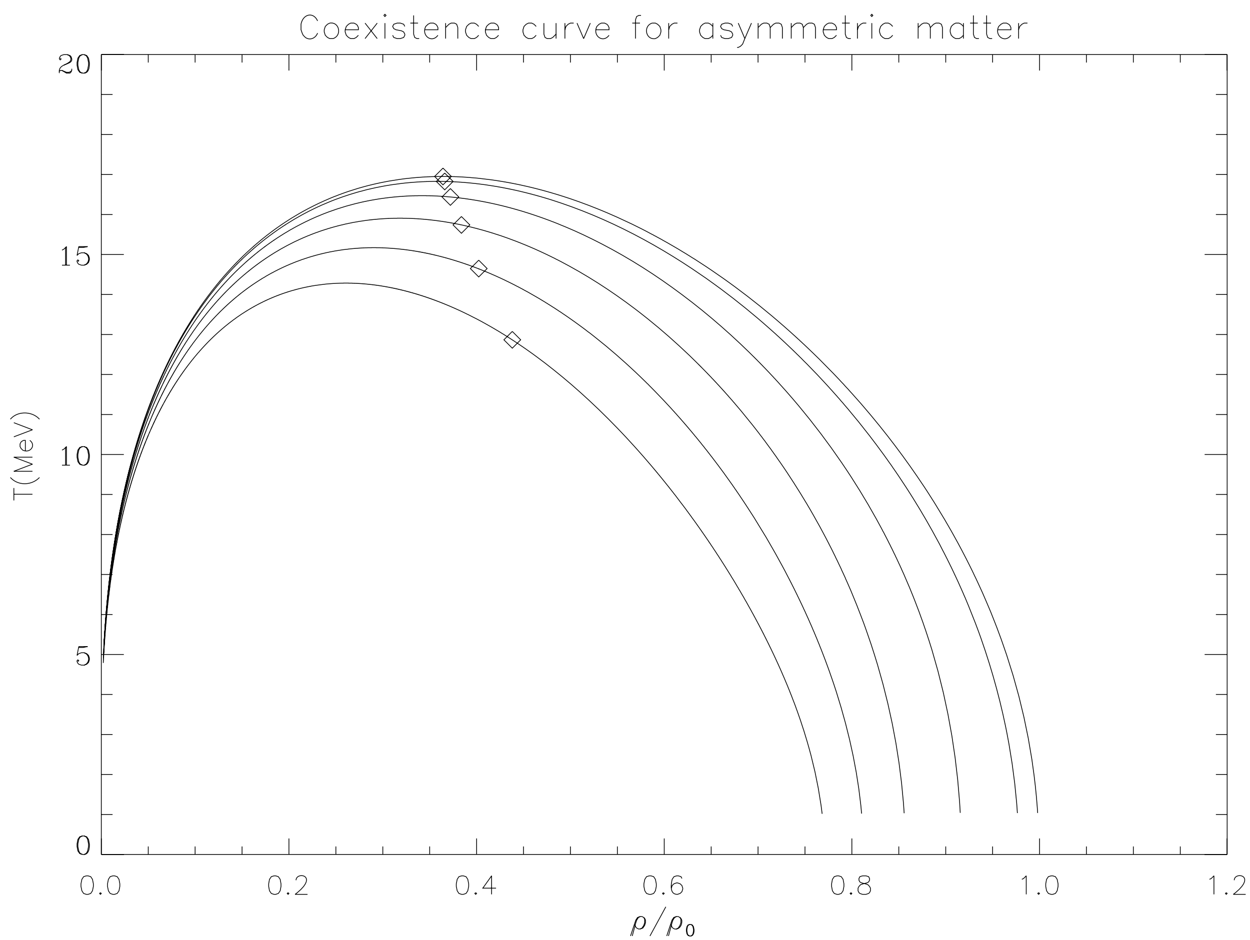
Table 1: Comparsion of the results from Steiner et al(2004) and our FRTF model

Nucleus	Property	Experiment	Potential	FT	FRTF
^{208}Pb	r_{ch} (fm)	5.50	5.41	5.41	5.38
	BE/A(MeV)	7.87	7.87	7.77	8.01
	δR(fm)	0.12 ± 0.05	0.19	0.20	0.15
^{90}Zr	r_{ch} (fm)	4.27	4.18	4.17	4.10
	BE/A(MeV)	8.71	8.88	8.65	8.77
	δR(fm)	0.09 ± 0.07	0.075	0.093	0.064
^{40}Ca	r_{ch} (fm)	3.48	3.40	3.34	3.22
	BE/A(MeV)	8.45	8.89	8.61	8.47
	δR(fm)	-0.06 ± 0.05	-0.044	-0.046	-0.036

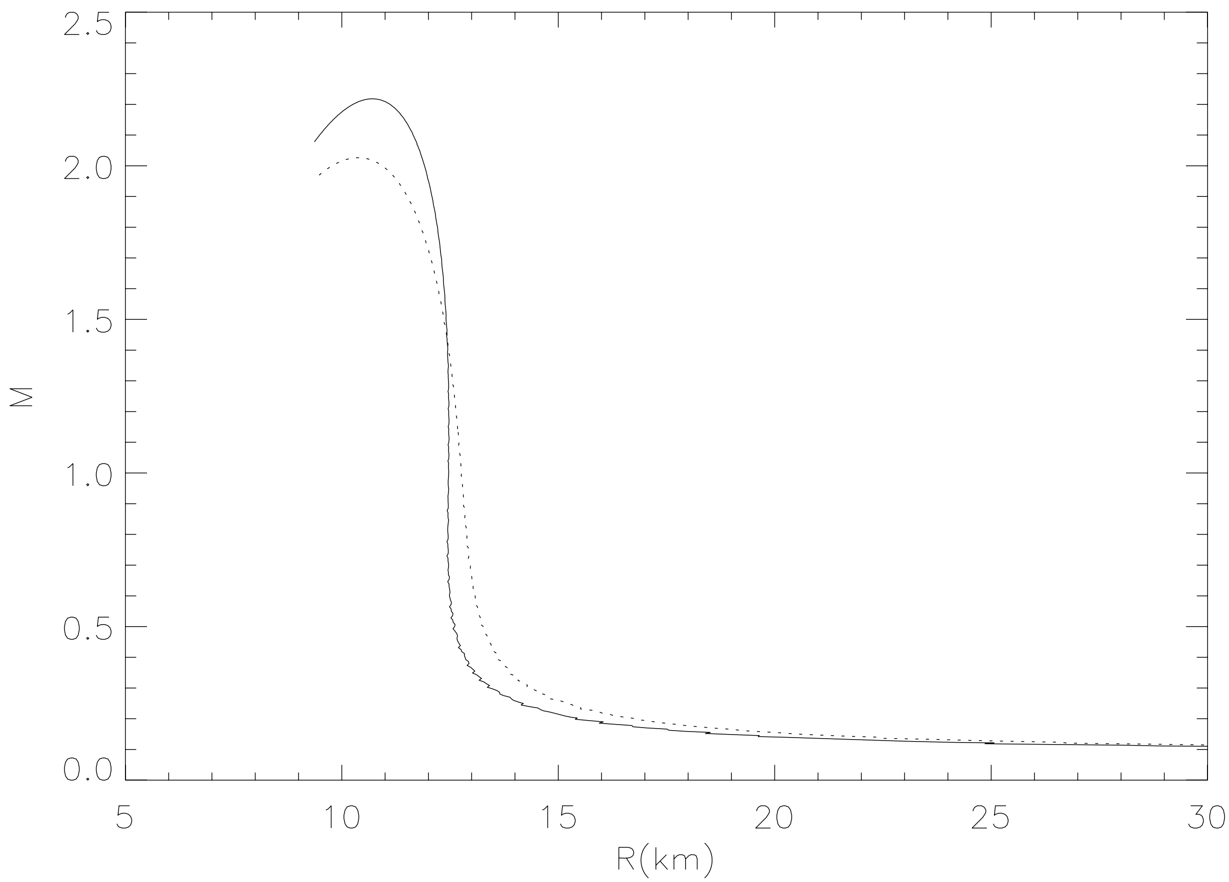


Binding energy per particle
−7.6
−7.8
−8.0
−8.2
−8.4
−8.6
−8.8
−9.0
B(MeV)
0
50
100
150
200
250
A(N+Z)


Contour plot of binding energy
140
120
100
80
60
40
20
0
Z
0
50
100
150
200
N
-7.80000
-8.00000
-8.20000
-8.60000



Coexistence curve for asymmetric matter
T(MeV)
0
5
10
15
20
0.0
0.2
0.4
0.6
0.8
1.0
1.2
ρ/ρ_0



2.5
2.0
1.5
1.0
0.5
0.0
M
5
10
15
20
25
30
R(km)

Further Work

i) New interaction form(density dependent, momentum dept..)

ii) Nuclear pasta phase(BCC, slab, cylinder, bubble...)

iii) Protoneutron star profile(entropy per baryon, mass and radius...)

iv) E.O.S table for core collapse supernova

v) Nuclear fragmentation