

Soft EoS from heavy-ion data and the implications for compact stars

Irina Sagert ¹

¹Institute for Theoretical Physics, University of Frankfurt, Germany

Ladek Zdroj, The Complex Physics of Compact Stars

KaoS Experiment

- Subthreshold production of K^+ by multiple NN collisions or secondary collisions
- Comparison of Kaon production in Au+Au and C+C collisions to reveal effects from the compressibility
- Nuclear matter is compressed up to $3n_0$ for energies of 1 - 1.5 AGeV
- Kaons are predominantly produced at $2n_0$

→ $K_0 \sim 200$ MeV can describe the trend of Kaon production data

Compressibility and Mass-Radius relation of Compact stars

To Do:

Using a soft equation of state ($K_0 \sim 200$ MeV) calculate the dependence on K_0 and on the symmetry term of:

- 1 Maximum masses of neutron stars
(Prakash et al. 1988 \rightarrow Result: $M_{max} \leq 2 M_\odot$)
- 2 Low mass stars ($M_{star} \sim 1.18 M_\odot$)
(Horowitz and Piekarewicz)
- 3 Highest possible mass
(Rhoades and Ruffini)
- 4 Onset of exotic matter/quark matter

Phenomenological EoS

Equation of State

$$\frac{\epsilon(n)}{n} = m_n (1 - x_p) + m_p x_p + E_0 u^{2/3} + \frac{A}{2} u + \frac{B}{\sigma+1} u^\sigma + (1 - x_p)^2 S(u)$$

$$S(u) = (2^{2/3} - 1) E_0 (u^{2/3} - F(u)) + S_0 F(u), F(u) = u^\alpha$$

where

- E_0 ... average kinetic energy of symmetric matter at n_0
- $u = n/n_0$
- σ, A, B ... parameters depending on K_0 and B_E :
- $B_E = (E/A - m_n)|_{n_0} \sim 16 \text{ MeV}$
- $K_0 = 9 \frac{dp}{dn}|_{n_0}$
- S_0 ... asymmetry energy at n_0
- x_p ... proton fraction

Ingredients for the EoS

Parameters depend on saturation density, binding energy, compressibility and asymmetry energy

Variation of values for

- $K_0 = 150\text{MeV} - 200\text{MeV}$
- $S_0 = 28\text{MeV} - 32\text{MeV}$
- $\alpha = 0.7 - 1.1$
- $n_0 = 0.15\text{fm}^{-3} - 0.17\text{fm}^{-3}$

Ingredients for the EoS

- Center of the star: Phenomenological EoS
- Inner crust: Negele and Vauterain
- Outer crust: Hempel et al.

Maximum Mass

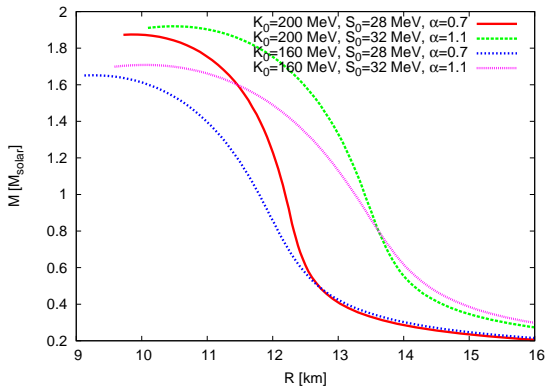


Figure: $n_0 = 0.16 \text{ fm}^3$

Maximum Mass

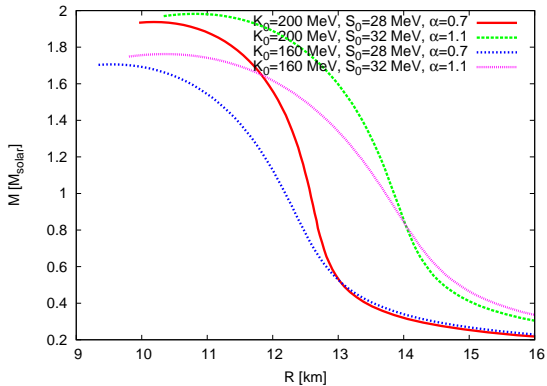
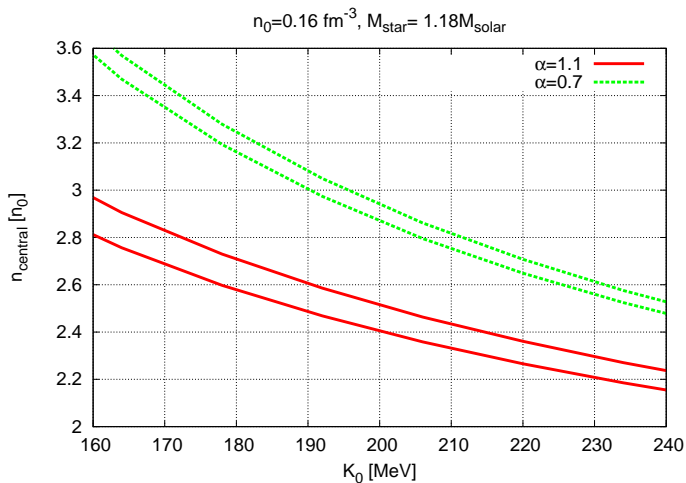
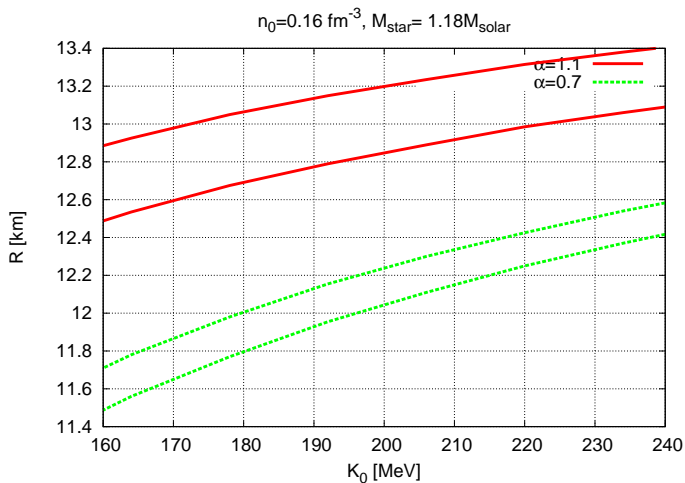


Figure: $n_0 = 0.15 \text{ fm}^{-3}$

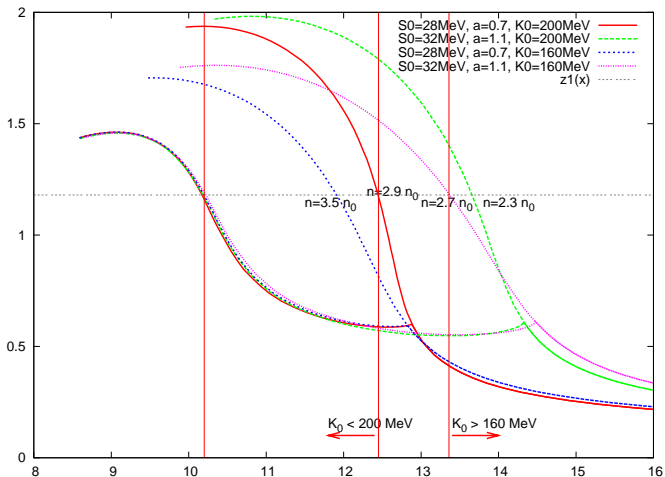
1.2 M_{\odot}

Measurement of a low mass pulsar with $M_{star} \sim 1.18 \mp 0.02 M_{\odot}$.

$1.18 \pm 0.02 M_{\odot}$ 

$1.18 \pm 0.02 M_{\odot}$ 

Hybrid stars



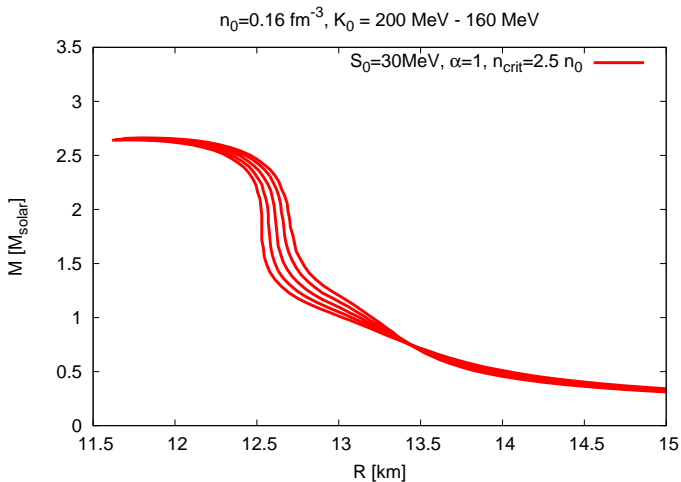
Stiffest EoS

Stiffest **causal** EoS: $p = \epsilon$ gives the absolut highest mass of a compact star.

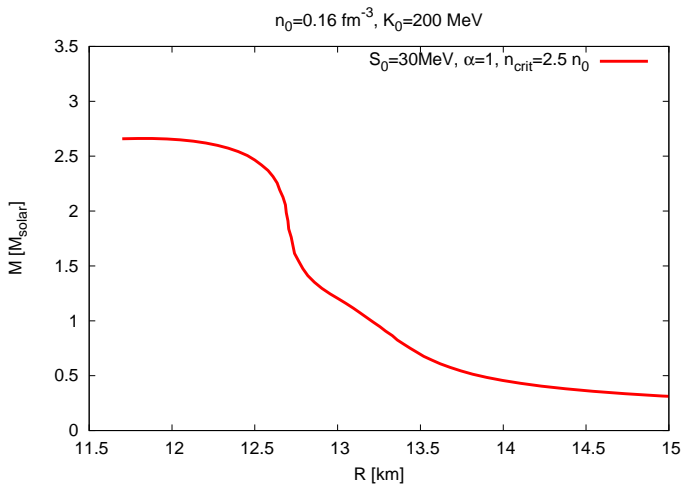
Construction of EoS:

- For low densities EoS should fullfill the softness constraints from KaoS
- For high densities the EoS goes into the stiffest EoS

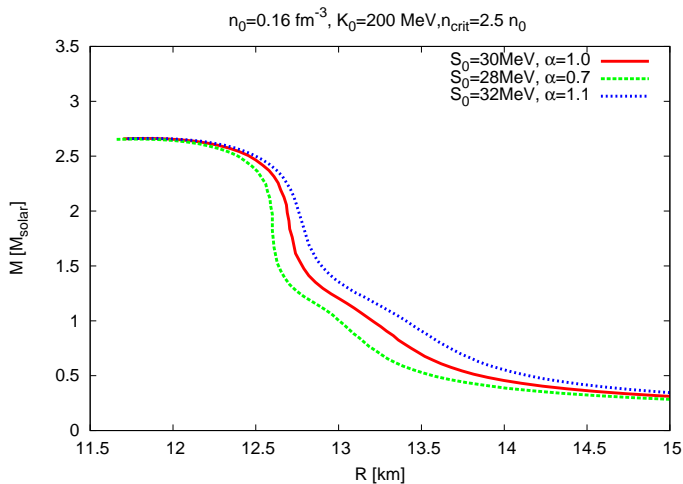
Stiffest EoS



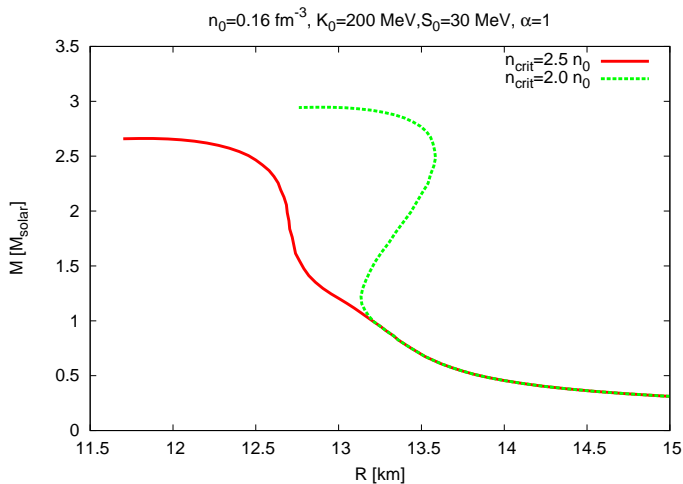
Stiffest EoS



Stiffest EoS



Stiffest EoS



Stiffest EoS

