Estimating the variation of neutron star observables by dense nuclear matter properties

[1] G.G. Barnafoldi, A. Jakovac, P. Posfay, Phys. Rev. D 95, 025004

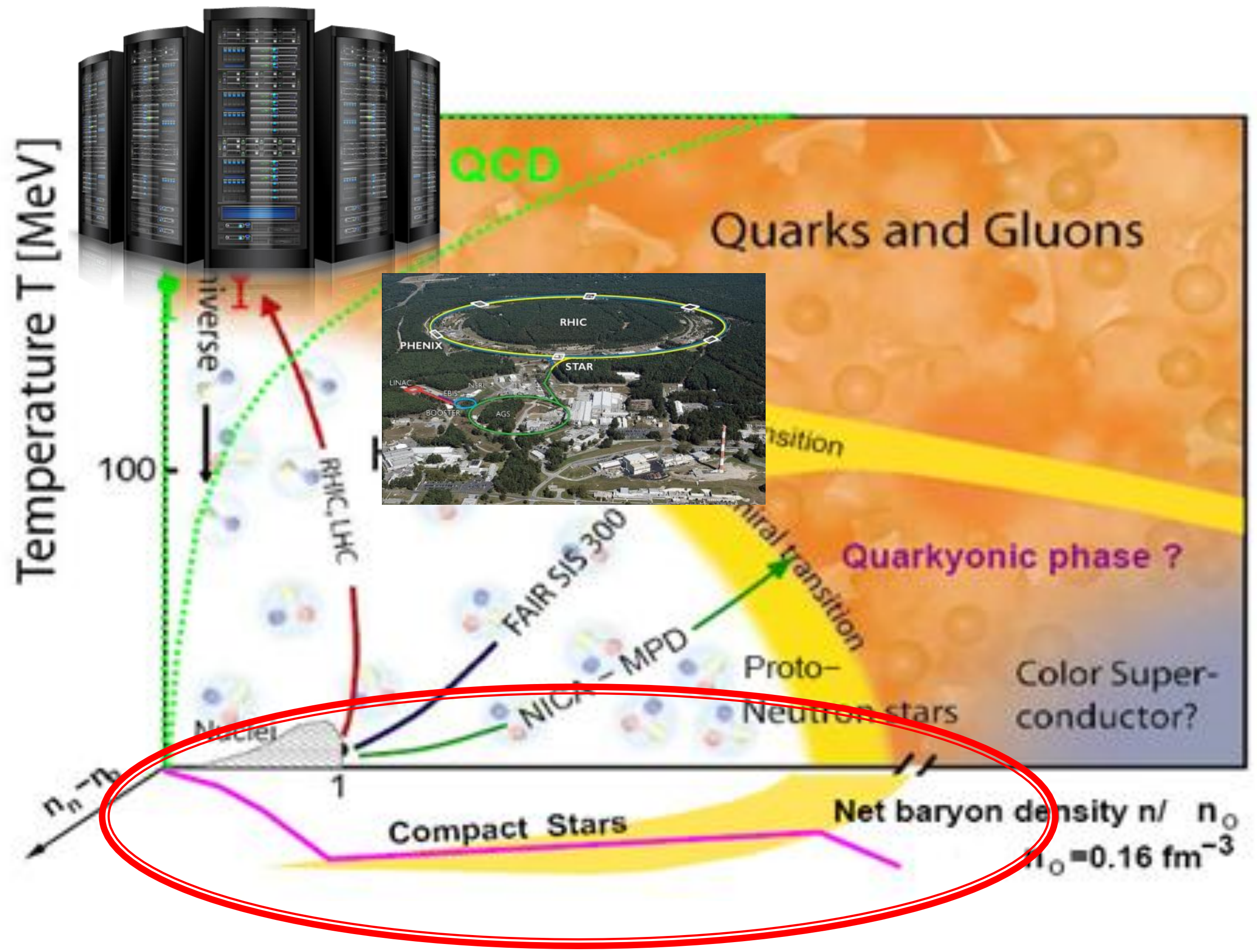
[2] G. Barnaföldi, P. Pósfay, A. Jakovác, Phys.Rev. C97 (2018) no.2, 025803

[3] Pósfay, P., Barnaföldi, G., & Jakovác, A. PASA (2018), *35*, E019.

Péter Pósfay

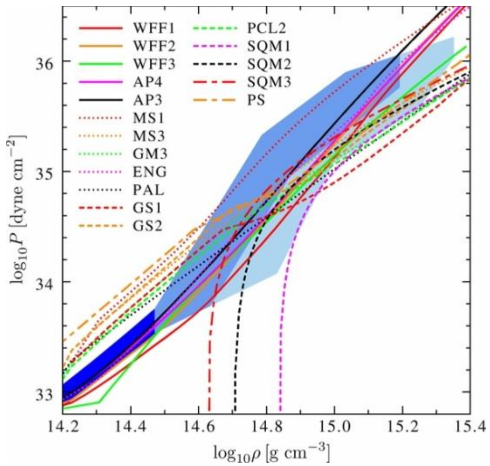
Supervisors: Antal Jakovác, Gergely Barnaföldi

Motivation

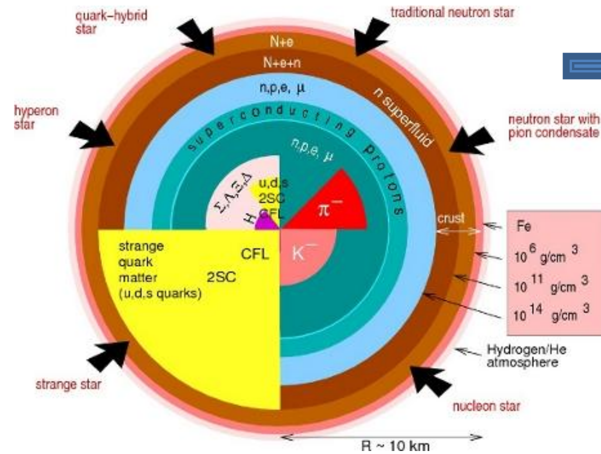

QCD
Quarks and Gluons
Temperature T [MeV]
100
RHIC
PHENIX
STAR
RHIC,LHC
FAIR SIS 300
NICA - MPD
Quarkyonic phase ?
Proto-
Neutron stars
Color Super-
conductor?
Nuclei
1
Compact Stars
Net baryon density n/ n_0
n_0=0.16 fm^{-3}

From nuclear matter to neutron stars

EoS



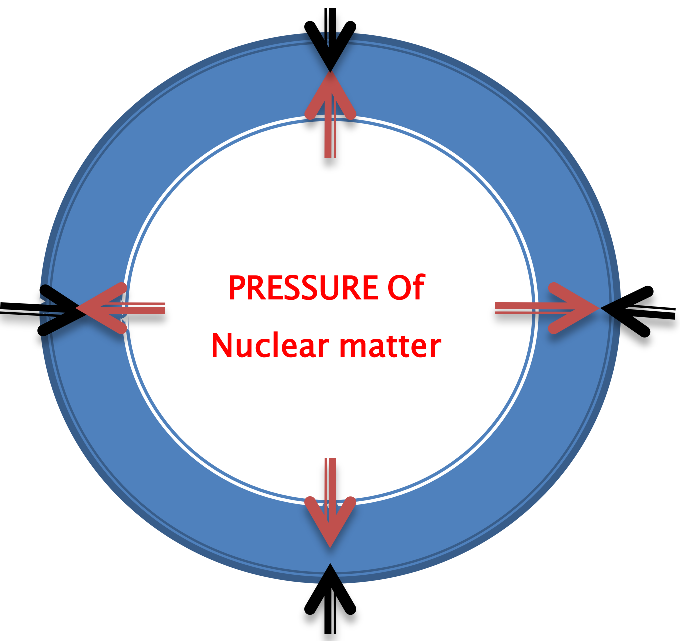
Solve TOV equations at given central energy density



Mass
Radius

Hydrostatic equilibrium–TOV equations

Weight of upper layers



Assumptions: spherical symmetry, isotropy, static

$$\frac{dP}{dr} = -\frac{G\varepsilon(r)m(r)}{r^2}\left[1+\frac{P(r)}{\varepsilon(r)}\right]\left[1+\frac{4\pi r^3 P(r)}{m(r)}\right]\left[1-\frac{2Gm(r)}{r}\right]^{-1}$$

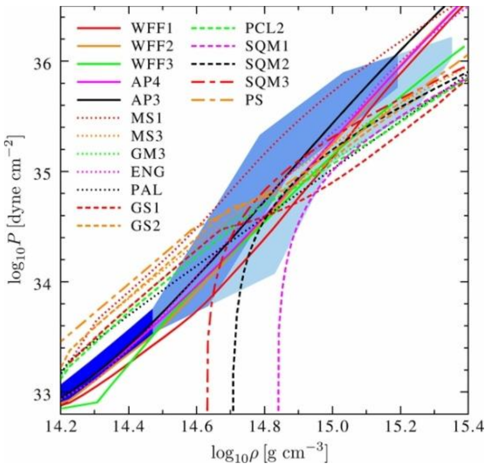
Relativistic corrections

$$\frac{dm}{dr} = 4\pi r^2 \varepsilon(r)$$

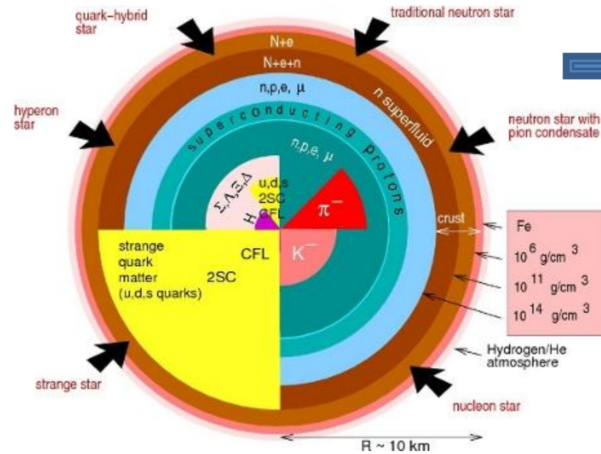
We need the equation of state for numerical integration: $P(\varepsilon)$

From nuclear matter to neutron stars

EoS



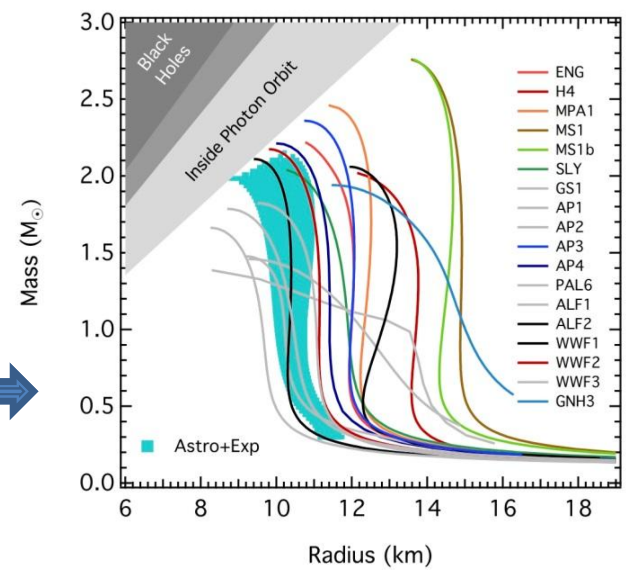
Solve TOV equations at given central energy density



Mass
Radius

Solve TOV equations for increasing values of central energy density.

M–R diagram



Péter Pósfay , ELTE, Wigner RCP

Fitting parameters of nuclear matter

Parameter	Value
Saturation density	0,156 $1/fm^3$
Binding energy	-16,3 MeV
Nucleon effective mass	0,6 M_N
Nucleon Landau mass	0,83 M_N
incompressibility	240 MeV

Incompressibility

$$K = k_F^2 \frac{\partial^2(\epsilon/n)}{\partial k_F^2} = 9 \frac{\partial p}{\partial n}$$

Landau mass

$$m_L = \frac{k_F}{v_F} \qquad v_F = \left.\frac{\partial E_k}{\partial k}\right|_{k=k_F}$$

$$m_L = \sqrt{k_F^2 + m_{N,eff}^2}$$

The effective mass and Landau mass are not independent!

Modified Walecka-model (Meanfield)

Nucleon effective mass

$$\mathcal{L}_{MF} = \sum_{i=1,2} \bar{\psi}_i \left(i\partial\!\!\!/ - m_N + g_\sigma \overline{\sigma} - g_\omega \gamma^0 \overline{\omega}_0 \right) \psi_i$$

Proton and neutron

$$-\frac{1}{2} m_\sigma^2 \overline{\sigma}^2 - \lambda_3 \overline{\sigma}^3 - \lambda_4 \overline{\sigma}^4$$

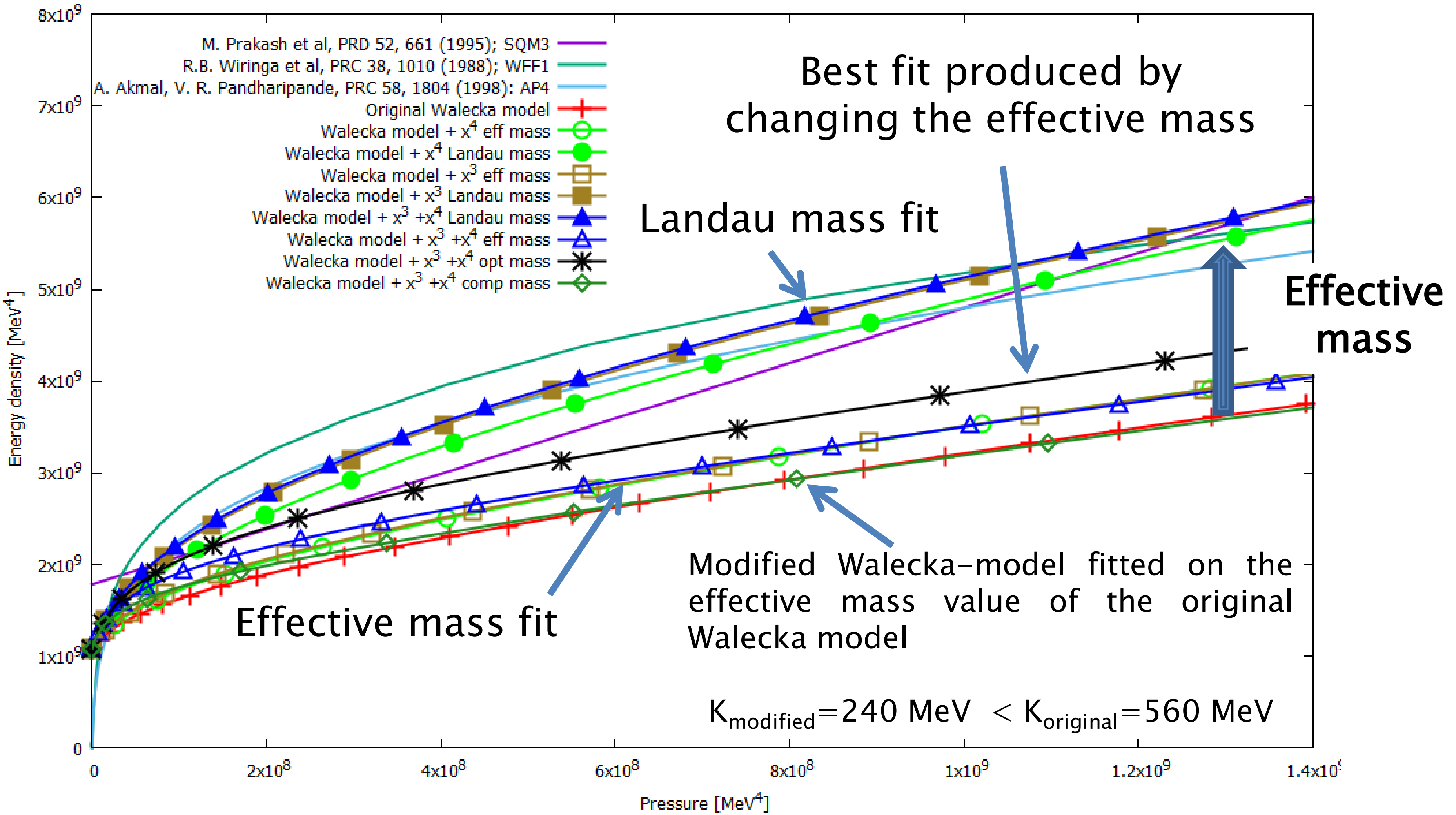
Scalar meson self interaction terms

Extra terms

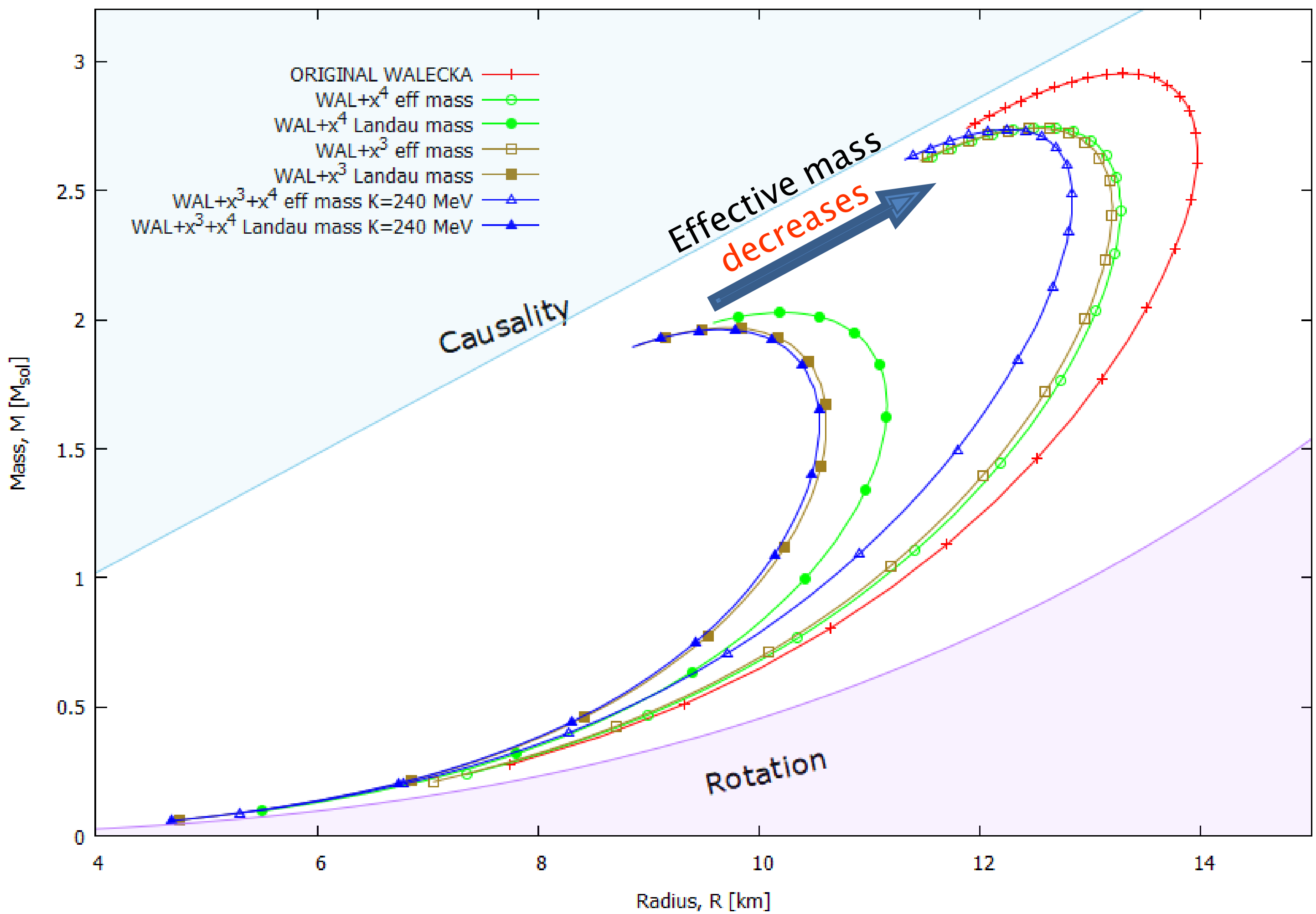
$$+\frac{1}{2} m_\omega^2 \overline{\omega}_0^2$$

Vector meson

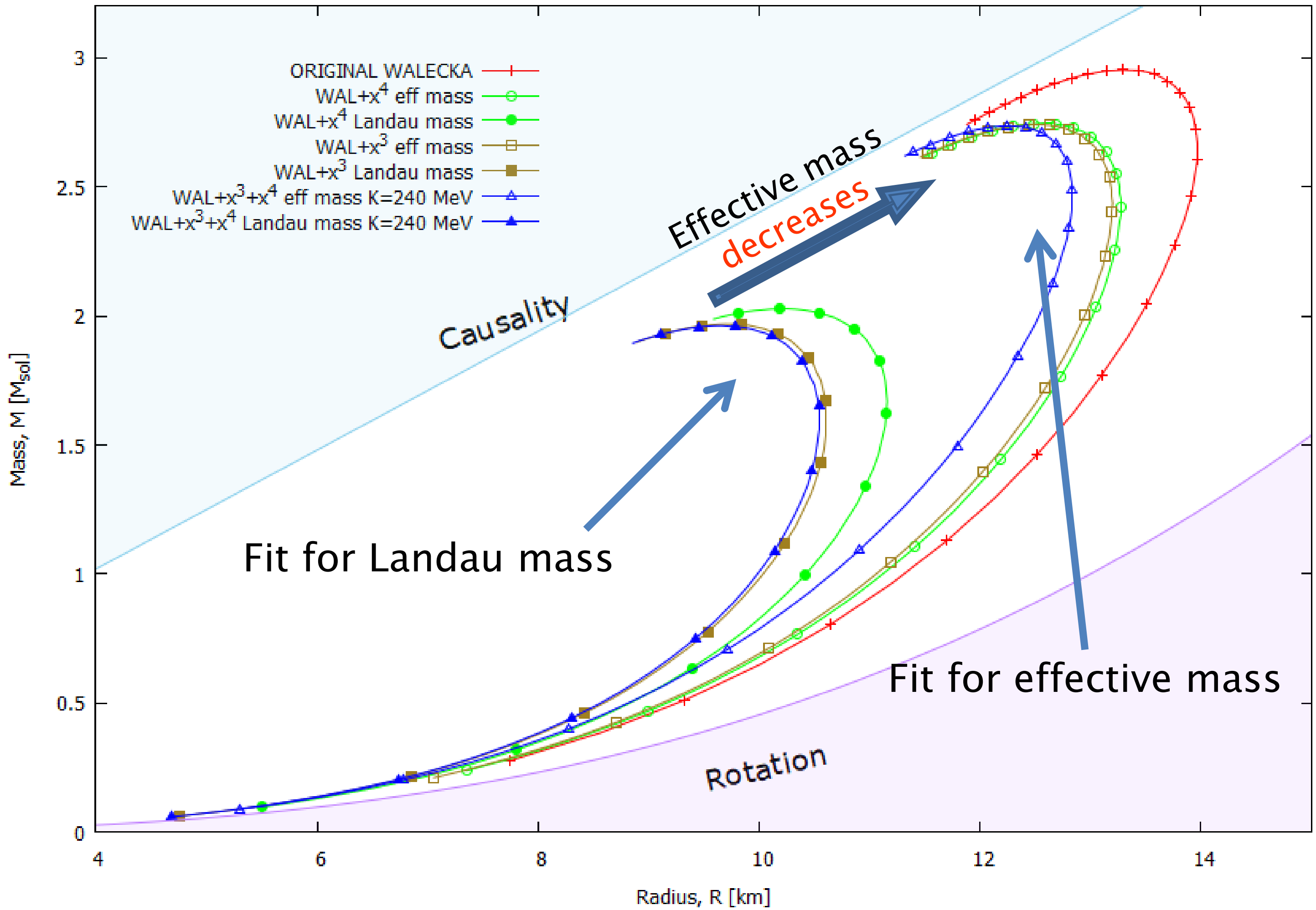
EoS of different models



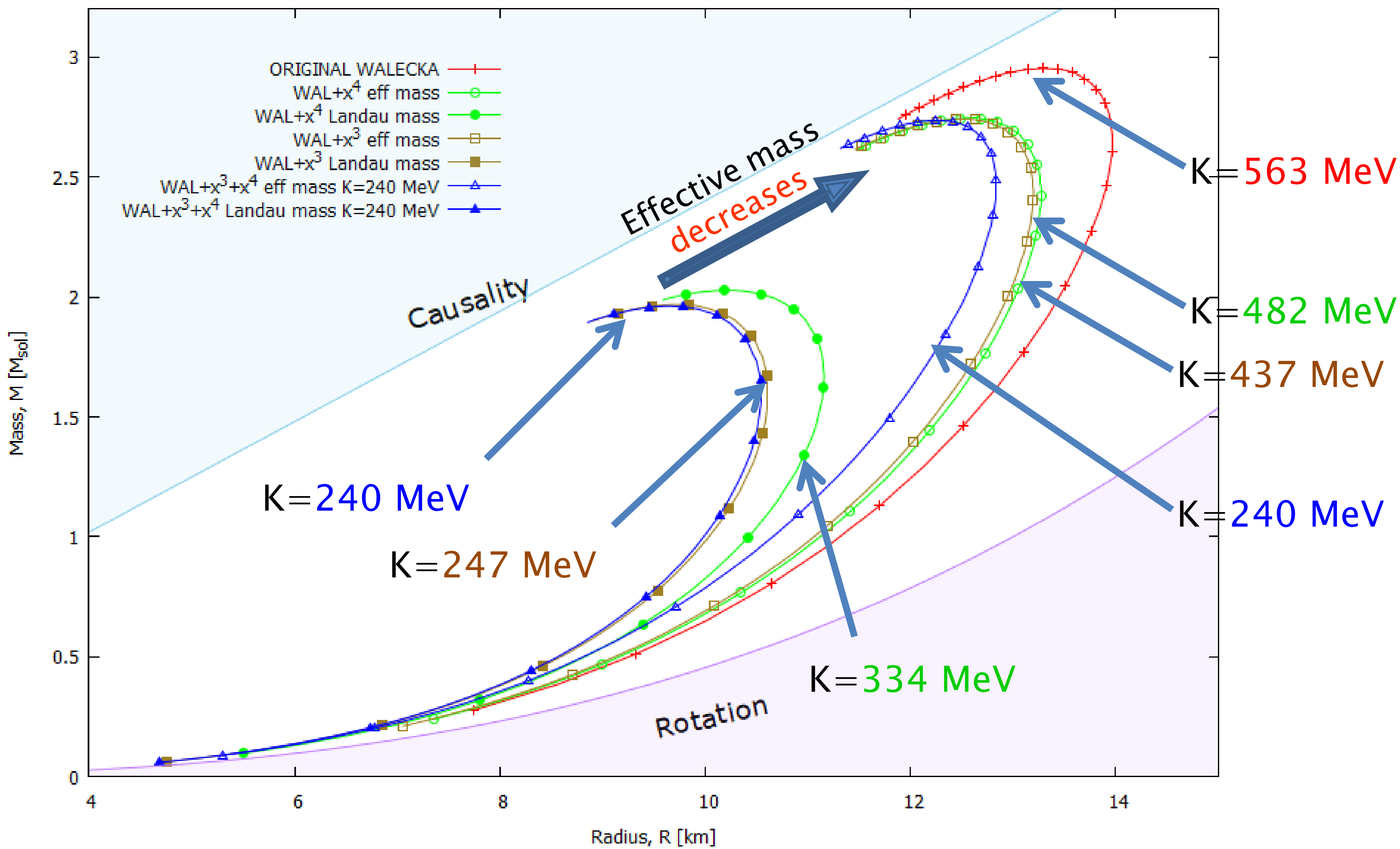
M-R diagrams corresponding to various models and fits



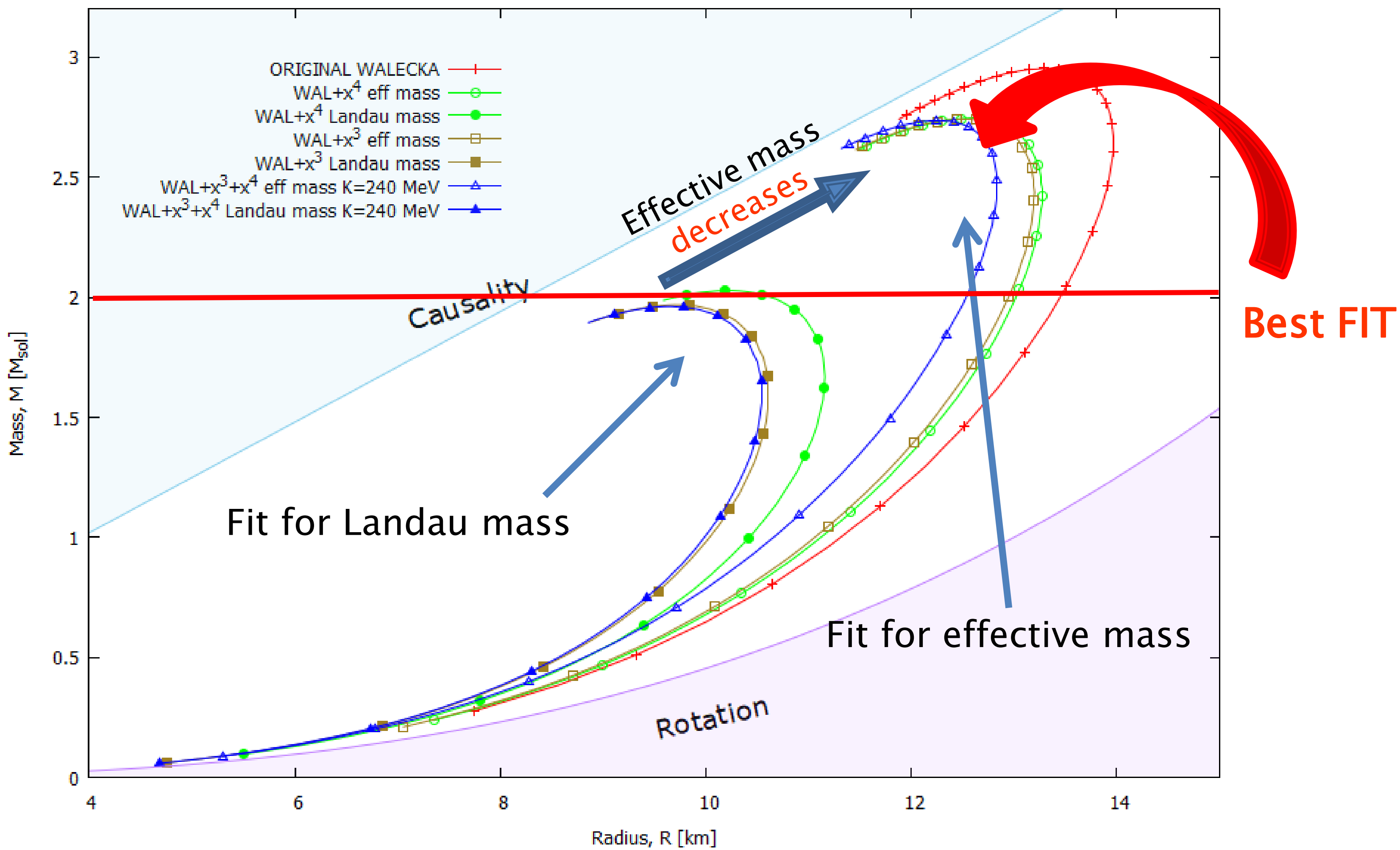
M–R diagrams corresponding to various models and fits



M–R diagrams corresponding to various models and fits

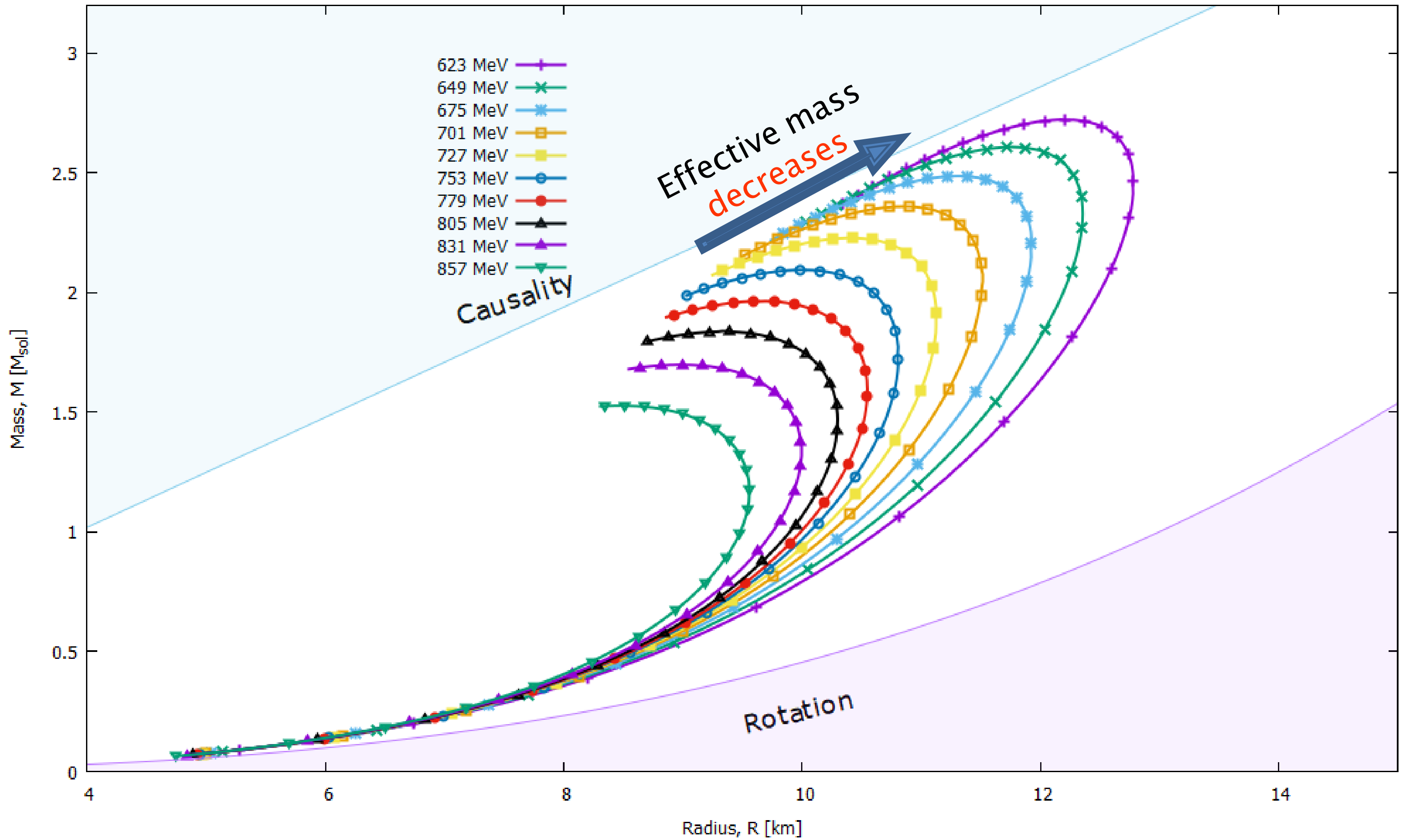


M–R diagrams corresponding to various models and fits



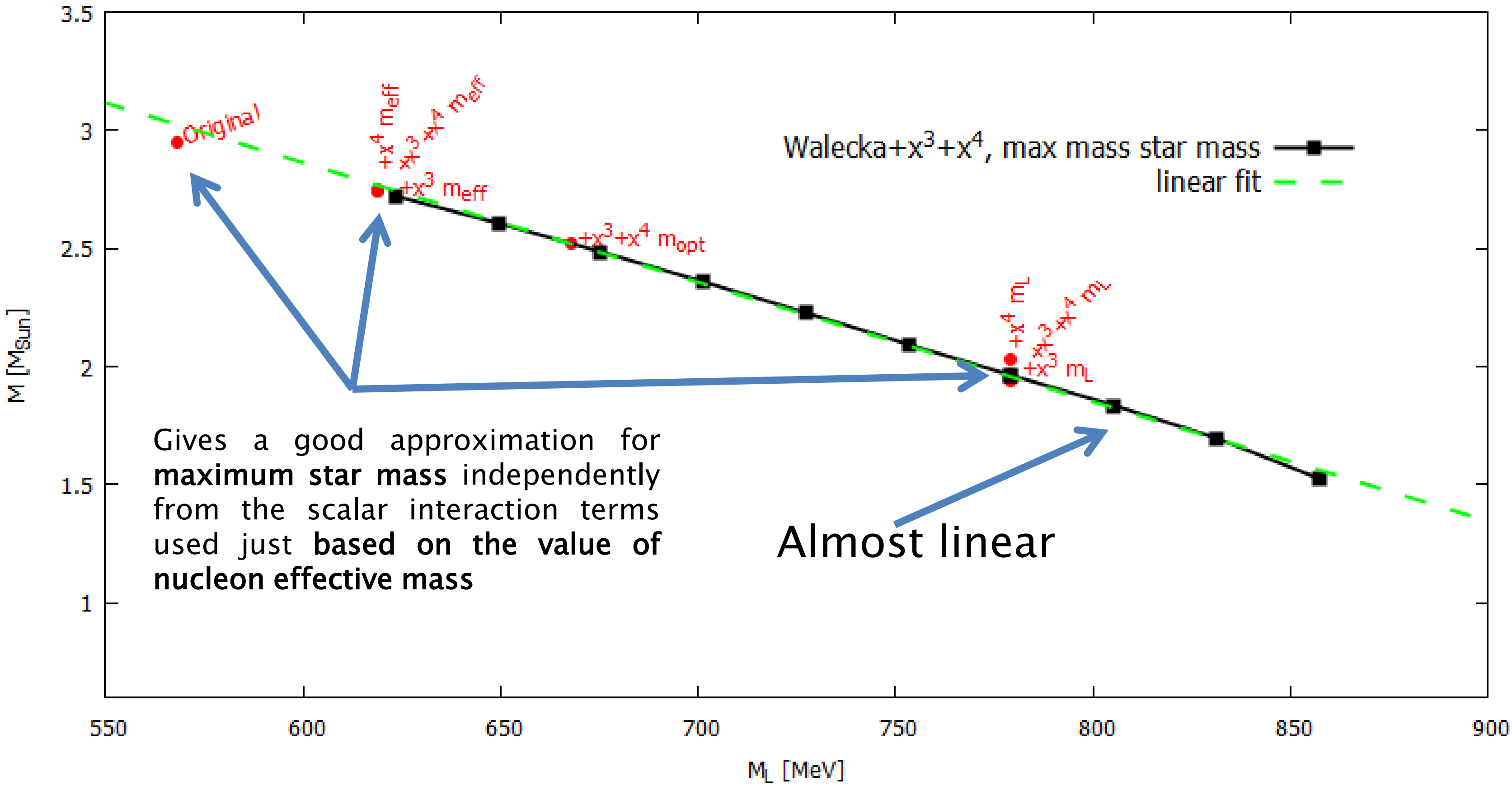
Interesting observation

Calculate the **M-R diagrams** corresponding to the modified Walecka model fitted to different values of **Landau (effective) mass**



Interesting observation

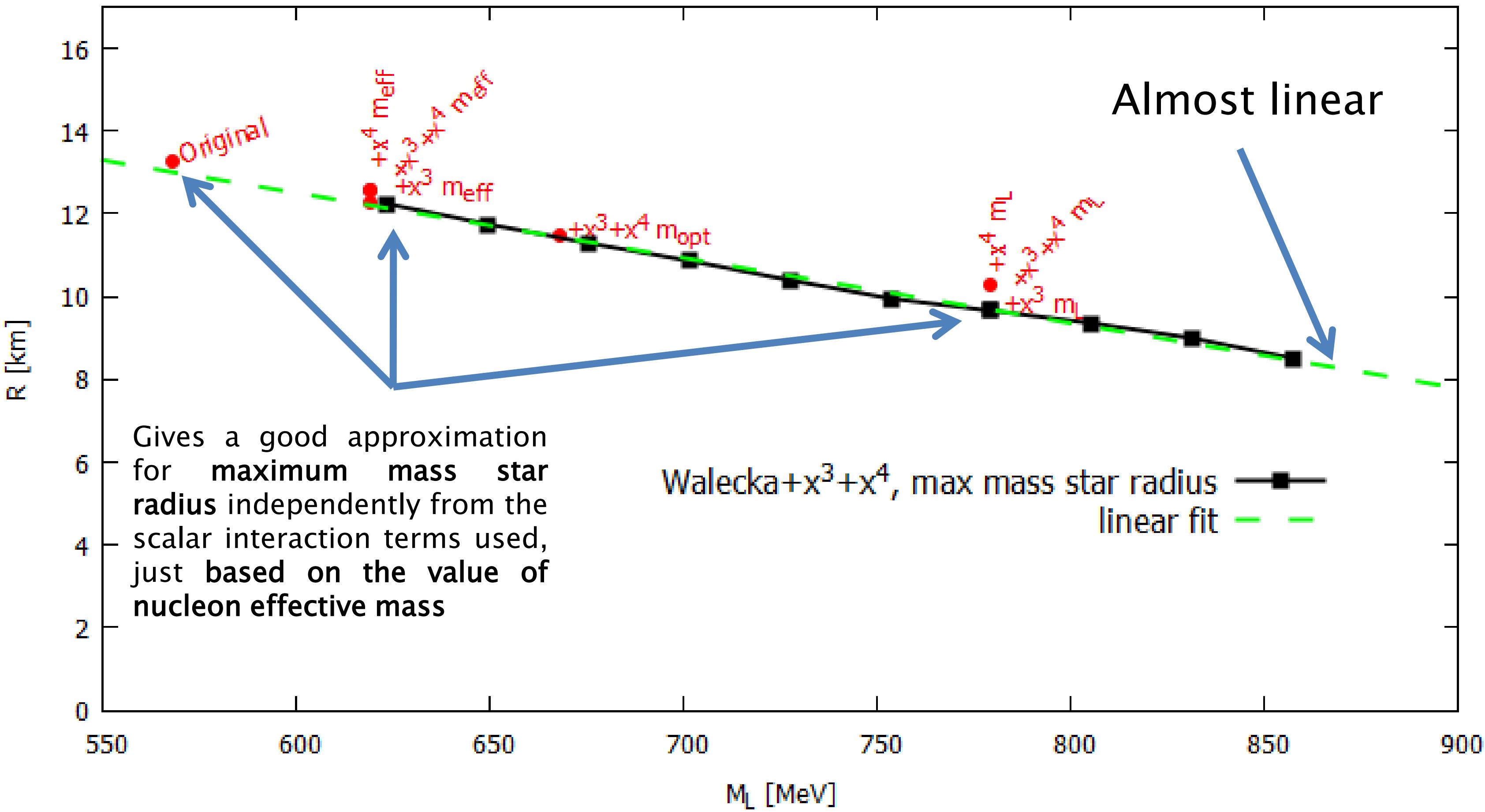
Plot maximum star mass as function of Landau-mass



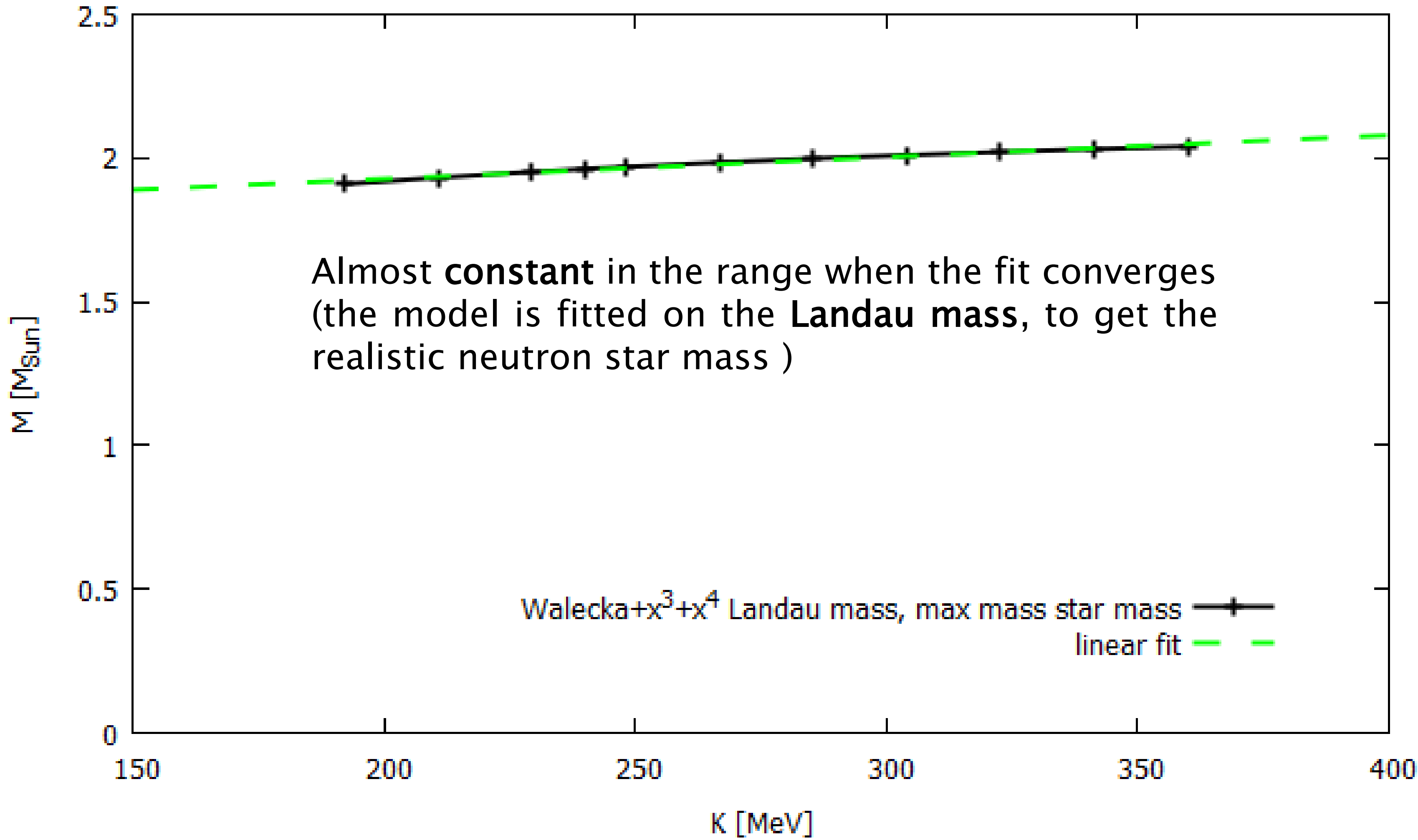
Gives a good approximation for **maximum star mass** independently from the scalar interaction terms used just **based on the value of nucleon effective mass**

Interesting observation

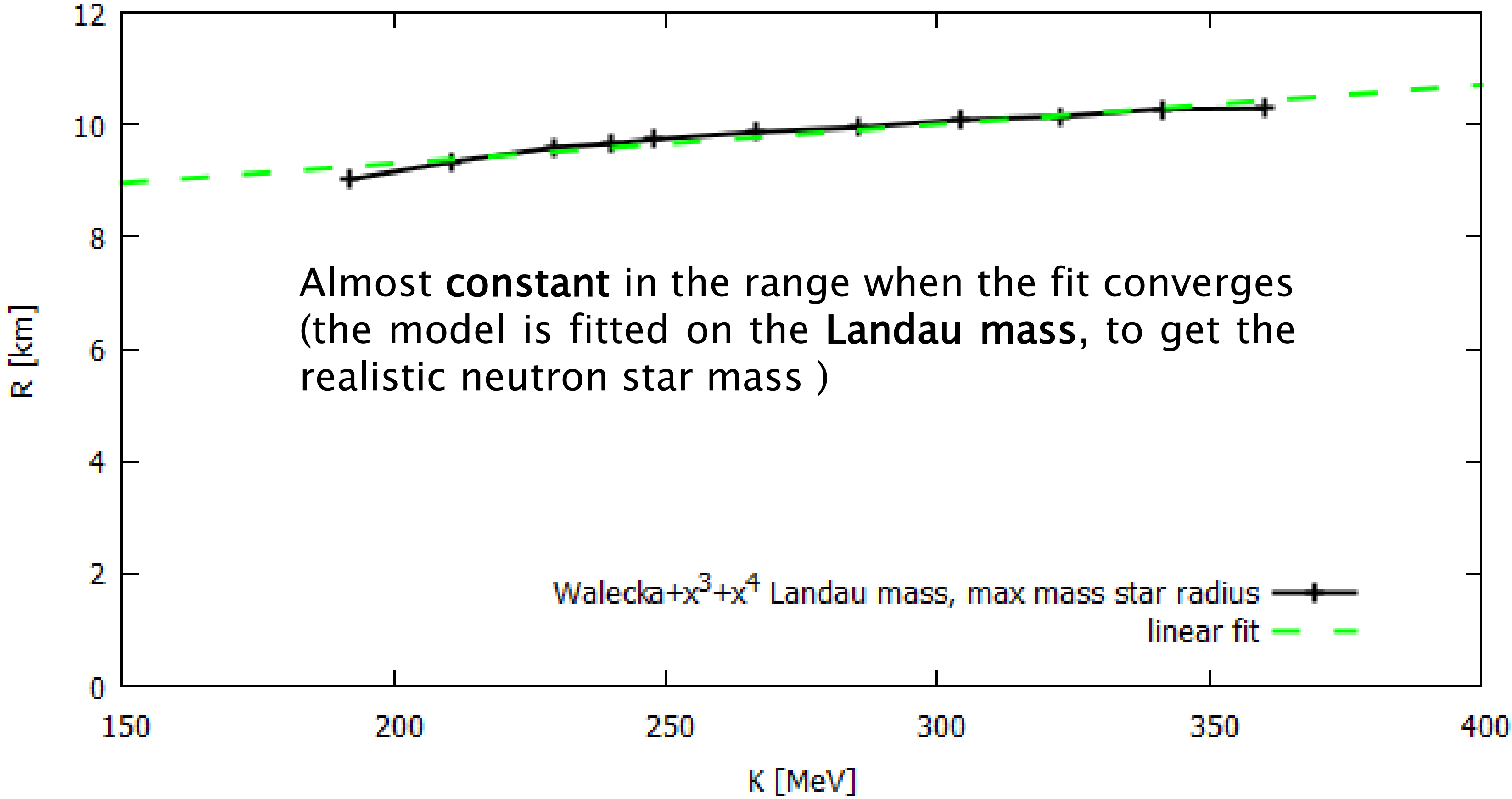
The same can be done with maximum mass star radius



What about compressibility



What about compressibility



Thank you for the attention!

http://pospet.web.elte.hu/

Köszönetnyilvánítás:
A munka az OTKA, NK106119, K104260, K104292, K120660, *TET 12 CN-1-2012-0016* , NewCompStar COST action 1304, és NKM-81/2016 MTA-UA bilaterális mobilitási program támogatásával készült.